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THE DEVELOPMENT OF THE PRETERM INFANT'S RESPONSIVENESS TO AUDITORY AND TACTILE SOCIAL STIMULI PRIOR TO 40 WEEKS' POSTCONCEPTIONAL AGE

by

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ABSTRACT

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Despite concern that preterm infants receive inappropriate tactile and auditory stimulation because of early birth, few studies have explored the development of responsiveness to tactile and auditory stimulation prior to 40 weeks' postconceptional age. The present research traced longitudinally the development of responsiveness to tactile and auditory stimulation of 14 preterm infants born at 30 or less weeks' postconceptional age. The preterm sample was divided into three groups (well, moderately ill, and sick) to assess the effects of illness. All infants were assessed three times per week from 30 to 34 weeks' postconceptional age. Body movement, eye movement, heart rate, smiles, hand-to-mouth activity, and "avoidance" signals of grimaces, cries, yawns, and tongue protrusions were assessed in response to (a) auditory stimulation in the

form of talking, (b) tactile stimulation in the form of touching/stroking, and (c) the combination of talking and touching. Further, these infants were assessed weekly for the development of neurological reflexes and responsiveness to the orientation items from the Brazelton Neonatal Behavioral Assessment Scale. When a pre-stimulus period was compared to a stimulus condition, preterm infants were found to respond to talking with significantly more eye movement; to touching with significantly more body movement; and to the combination of talking and touching with more body movement. Significant effects of illness were found when smiles, hand-to-mouth activity, and "avoidance" signals were assessed. During all the stimulation conditions the well infants had significantly more smiles and hand-to-mouth activity. During talking and the combination of talking and touching the sick infants also showed significantly more "avoidance" signals. Sick infants also performed less well than the well infants on the Brazelton orientation items and on some of the neurological exam items.

The findings of this study suggested that responsiveness to social stimuli, talking and touching, develops quite early, even before the time of usual birth, and is minimally affected by illness. Behaviors shown by these infants are those likely to attract the caregiver's attention, suggesting that the preterm infant is capable of behaviors which will engage the caregiver and possibly serve as the roots of social behavior.

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CHAPTER I

INTRODUCTION

The Problem

The present study traced the development of the preterm infant's responsiveness to sensory stimuli, specifically the talking and touching provided by caregivers. The developmental period studied began at birth between 26 and 30 weeks' postconceptional age (10 or more weeks before term) and continued until close to the time of usual birth at 40 weeks' postconceptional age. The preterm infants studied were appropriately grown for their gestational age and free of congenital abnormalities. Some of these infants experienced severe life-threatening medical complications during their intensive care nursery stay, complications thought to place their developing nervous system at risk; others only experienced mild to moderate complications. Sensory responsiveness was assessed by analyzing changes in body movement, eye movement, facial and mouth activities, and heart rate. The major questions were (a) how does the infant respond to talking and touching; (b) how early in development does the premature infant begin to respond with body movement, eye movement,

facial activity, or heart rate change to talking and touching; (c) how does the nature of the response change with increasing age; and (d) how does the development of responsiveness differ for severely ill preterm infants versus those less ill?

The development of responsiveness to sensory stimuli in the preterm infant is of both theoretical and practical interest for a number of reasons. At least four such interests guided the present study. First, the preterm infant offers new opportunities for examining carefully the early development of sensory responsiveness. Second, the preterm infant suffering severe medical complications that may compromise central nervous system development provides an opportunity to relate variations in central nervous system development to the development of responsiveness. Third, understanding the developmental course of responsiveness could assist us in our efforts to structure an intensive care nursery environment more conducive to normative growth and development. Fourth, and perhaps most important, an understanding of infant responsiveness will help us understand its impact upon caregivers and aid them in caring for their "different" infant.

Although preterm birth is an unfortunate occurrence for the child and family, these early births do provide the opportunity to observe behavioral development at a time when behavior is ordinarily less accessible and thus to trace the course of behavioral responsiveness to sensory input during this period. The concept of "probabilistic epigenesis"

(Gottlieb, 1970) suggests that the behavioral development both prenatally and postnatally of the individual within a given species does not follow an invariant or inevitable course; the sequence of individual behavioral development is probably plastic, depending upon the interplay of numerous factors. We thus should not be surprised to find differences at 40 weeks' postconceptional age between the responsiveness of fullterm infants and infants who were born 10-12 weeks before term and who were subjected to the quite different experiences of the intensive care nursery (ICN). The ICN is quite unlike the usual home environment of the fullterm infant and also quite unlike the intrauterine environment. Therefore, the study of the preterm infant can shed some light upon both the very young organism's capacities for sensory responsiveness and the modification of those capacities by major variations in environmental input.

Certainly the infant's degree of illness would seem to be an important factor in the development of behavioral responsiveness to sensory input. Several of the common illnesses hold potential both for direct deleterious effects on brain development and for indirect deleterious effects on the central nervous system by interfering with nutritional intake. Further, these pathological processes may alter the infant's concurrent ability to respond to stimuli, independent of their effect upon central nervous system development. Illness also alters the immediate environment of the infant. For example, whether the infant is cared for in an enclosed incubator or open bed is sometimes dictated by the degree

of illness, particularly respiratory status. Those infants requiring mechanical ventilation are frequently kept in open beds, whereas those not needing supplemental oxygen are often placed in incubators. It would appear, then, that the course of development may be altered by the infant's biomedical status. To date, however, few studies have compared the responsiveness of ill preterm infants to that of less ill preterm infants prior to their time of discharge from intensive care. Still fewer have contrasted the courses of behavioral development for these different groups of preterm infants.

In the last decade, many investigators have tried to provide the preterm infant with appropriate sensory stimulation during their long hospitalization. Few studies, however, have looked at the behavioral responsiveness of these infants to the various sensory stimuli presented; and, therefore, little information is available about the effects of a given stimulus at a particular age and hence about the "appropriateness" of the stimuli provided. An understanding of how sensory responsiveness develops could guide efforts to intervene with appropriate stimulation for the premature infant. For example, one might argue that stimulation should be provided that increases the infant's alertness without compromising the infant's physiologic equilibrium.

A further reason for studying the development of the preterm infant's behavioral responsiveness to social stimuli is to understand its impact on caretakers, both nurses and parents. Often the preterm infant

attached to considerable equipment appears to be regarded by the nurses as capable of very little responsiveness. Preterm infants may be seen as relatively unresponsive and unrewarding to care for, and even frustrating. Similarly, parents seem to have difficulty seeing their infant as responding to them (Brazelton, 1982) and often express anguish at their inability to make contact with their infant. Therefore, demonstrating the responsiveness of the infant might facilitate the beginning relationship between parent and child. Learning to read cues of receptiveness and responsiveness to sensory input might be an important skill for nurses and particularly for parents, who will be interacting with the child for years to come.

The present study was designed to help us understand more fully the development of the individual preterm infant's capacity for responsiveness to social stimuli. Four research literatures particularly germane to the problem and the design of the study were addressed. The first concerns the central nervous system development in human infants prior to the time of usual birth. These species-specific changes in central nervous system structure and function would appear integrally involved with the development of the behaviors studied: body movement, eye movement, facial expression, and heart rate. In order to understand the behavior, there must be understanding of the underlying development of the nervous system. Also included in this literature are studies which measure developmental changes in the functioning of the central nervous system through electroencephalogram measurements.

A second literature concerns developmental changes in the behaviors observed in preterm infants from birth until the time of usual birth. This literature does not focus upon responsiveness to sensory stimuli, but rather more general observations about basic behavioral capacities. Observations of fetal behavior gained from serial ultrasound examination are also included because they are a major source of information regarding normal fetal behavioral development. Behavioral changes will be traced week by week in an attempt to link observed behavioral changes in the fetus and preterm infant with anatomical changes in the nervous system. This small literature offers a picture of changes in body movement, eye movements, and reflexive behavior from 20 to 41 weeks' postconceptional age.

A third, more extensive literature is that pertaining to evidence for the sensory responsiveness of the preterm infant. This literature gives us evidence that the preterm infant does respond to various types of sensory stimuli, although the sensory stimuli that have been studied are limited and little information is available about behavioral responsiveness to social stimuli or about developmental changes for the stimuli studied.

Finally, a fourth relevant literature examines the impact of sickness and various environmental factors on the early development of sensory responsiveness in animals and humans, particularly preterm infants. This literature is particularly important since preterm infants are subjected to multiple alterations in their environment that may be expected to alter their development.

Each of these four research literatures is examined in turn. The conclusions drawn from this examination are then summarized. Lastly, a rationale for the present study is presented.

Development of the Central Nervous System Prior to 40 Weeks' Postconceptional Age

Dorsal and Ventral Induction

Neuronal circuitry begins surprisingly early in fetal life, and the growing embryo manifests reflexive movements very early in gestation. Dorsal induction with formation of the spinal cord takes place within the first 4 weeks of gestation. In the next 2 weeks, ventral induction brings formation of the face and the major structures of the brain and brainstem. The first reflexive movement at the 5th-6th week of gestation coincides with synapse formation. In the 7th week when formation of the cortical plate of the neocortex occurs, synapses have been identified above and below the cortical plate but not in it (Berry, 1982; Molliver, Kostovic, & Van Der Loos, 1973).

Proliferation

The proliferative phase occurs during weeks 7 through 16; neurons and glial cells develop from the periventricular germinal matrix. Neuronal multiplication is completed by 18 weeks (Lemire, Loeser, Leech, & Alvord, 1975). In the cerebellum, synapses first appear around the 15th week, and by the 23rd week synapses are within the cortical plate (Berry, 1980).

Migration

The migration of cells to their final placement in the nervous system takes place between weeks 10 through 24 of gestation, overlapping with phases of maximal axonal and dendritic growth. The migration of cells usually takes place from the 3rd to 6th month of gestation. Cells migrate from their sites of origin in the subependymal germinal matrix to loci within the nervous system. Cells migrate from the germinal matrix zone to the surface of the ventricles and divide and return to their original position. Cells then migrate in waves through the mantle zone of the cortex into the marginal zone to form the cortical plate. Cells in subsequent waves take a more superficial position (Volpe, 1981). There are two basic types of migration: radial and tangential. Radial migration is the primary mechanism for formation of the cortex and deep nuclear structures. Tangential migration is generated in the germinal zone first over the external surface of the cerebral cortex and then inward to form the external granular layer. Further, tangential migration extends further inward to form the external granular cell layer then migrates inward to form the internal granular layer of the cerebellar cortex (Volpe, 1981).

Dendritic and Axonal Growth

Dendritic growth usually begins as migration ceases (Berry, 1980). In Stage 1, dendrites are short with an uneven diameter and leave the cell body at multiple sites. The dendrites of Stage 2 become more even in diameter and develop spines to form synapses. Stage 3 is marked by continuing development of the dendrites. During Stage 4 there is a gradual

reduction in the number of spines, and the spines become thicker and more regularly shaped (Lou, 1982). Dendrites appear to provide the major proportion of the membrane surface area for integration of synaptic inputs. In addition, dendritic spines are postsynaptic targets for a variety of afferent projections to cortical neurons. They, therefore, determine the potential functional synaptic competency of the maturing brain (Paldino & Purpura, 1979b). Axon systems develop para passu with the dendrites, and the adhesive interaction between growing axons and dendrites determines the physical characteristics of the dendritic field (Berry, 1980). The importance of this growth has been emphasized by Dobbings (1982), who suggested that normal function depends on the degree of dendritic development of the neurons and synaptic connectivity. Dendritic growth continues for some time after neurogenesis is complete. However, there is potential for growth continuing well into adulthood, probably accounting for some aspects of plasticity of the nervous system (Berry, 1980).

Maximal dendritic growth varies in different areas of the brain. The maximal phase of dendritic growth in the hippocampus, insula, and motor cortex occupies the first 18 to 24 weeks of gestation. With the vertical spread of axonal and dendritic terminals, there is a three-fold increase (Paldino & Purpura, 1979a). (The hippocampus is an area of the forebrain concerned with multiple functions such as modulation of sensory information to the thalamus and neocortex, emotionality, and memory. The insula is an area of cerebral cortex concerned with sensory and motor

activity of the abdominal viscera. Motor cortex refers to that area of cortex concerned with motor function.) By the 27th week of gestation, axons are more frequently found in relation to the pyramidal neurons, and by 33 weeks of gestation there is a greater density of axons in relation to the deep-lying hippocampal pyramidal neurons (Paldino & Purpura, 1979a; Purpura, 1975). (Pyramidal cells are a type of motor neuron. Giant pyramidal cells located in the cerebral cortex are called "Betz cells.") Similarly, dendrites begin to ramify in the cerebellum and have been found in the molecular layer of the cerebellar cortex by 24 weeks (Berry, 1980). After 28 weeks, somatic spines disappear in the cerebellum and the dendritic tree develops secondary and tertiary branches, and by 30 weeks following conception there are definitely recognizable Purkinje cells in the cerebellum (Berry, 1980). It is also at this time that the six layers of the cortex are apparent; however, differentiation is asynchronous between different regions. For example, the area corresponding to the trunk is more highly developed than the lower limbs, and the area of the lower limb is more highly developed than the upper limbs (Larroche, 1966).

Myelination

Myelination begins approximately at the 20th week of gestation, occurs by degrees, and continues well into the first decade of life (Gilles, Leviton, Dooling, & Wright, 1983). Even though myelin sheaths are not necessary for conduction of action potentials, before myelination the neurons usually have slower transmission rates, are limited in rate of

repetitious firing, and are prone to fatigue (Bronson, 1982). Estimates of the age of onset of myelination varies with the site (Gilles et al., 1983; Larroche, 1966). As would be expected from the earlier development of the nervous system, the spinal cord and its tract are the first to become myelinated. Both the posterior roots carrying sensory fibers and anterior roots carrying motor fibers are the first to be myelinated at around 20 weeks following conception. Myelination of the fasciculus cuneatus (carrying sensory fibers which respond to joint movement, hair movement, light touch, pressure, or vibration, and facilitate the reflex arc to the upper extremities) occurs around 24 weeks (Larroche, 1977). The fasciculus graecilis (carrying sensory fibers to the lower extremities) becomes myelinated at around 20 to 28 weeks following conception (Gilles et al., 1983; Larroche, 1966). Both the spinothalamic and spinocerebellar fasciculi carrying sensory and motor nerves, respectively, are myelinated at about the same time. The rubrospinal tract (carrying fibers connecting midbrain with the spinal cord, and whose function is to activate the contralateral flexor motor neurons and inhibit extensor neurons) is not myelinated until 32 weeks (Larroche, 1977). Another spinal midbrain tract, the tectospinal tract (carrying fibers involved in head-turning and upper limb movements) myelinates at about the same time. However, the corticospinal tracts, connecting spinal cord with the cortex, are not myelinated until term or beyond (Larroche, 1977).

Like the spinal cord, the brainstem is myelinated at varying times.

In the medulla, myelination of the medial lemniscus (carrying ascending fibers from the nucleus graecilis and cuneatus), medial longitudinal fasciculus (large association system of fibers through the brainstem and spinal cord), and inner division of the inferior cerebral peduncle (containing fibers interconnecting the cerebrum and brainstem with the spinal cord) occurs at around 24 to 26 weeks following conception (Larroche, 1977). (The nucleus graecilis receives fibers concerned with sensations from the leg and lower trunk, and the nucleus cuneatus receives impulses from the upper trunk, arm, and neck.) On the other hand, the pyramids and outer division of the inferior cerebral peduncle are not myelinated until 36 weeks following conception. In the pons and cerebellum, medial and lateral lemnisci and medial longitudinal fasciculi are myelinated at 24-26 weeks (Larroche, 1977). In the cerebellum, the lamellae of the flocculus (affecting balance) and vermis (affecting postural control and coordination of limbs) are myelinated by 32 weeks following conception (Larroche, 1977). However, the lamellae of the lateral hemispheres of the cerebellum (affecting controlled, skilled movements) are not myelinated until term. The pyramidal tract in the pons becomes myelinated by 36 weeks following conception (Larroche, 1977).

All of the cranial nerves except the olfactory, optic, and auditory are myelinated by 30 weeks' gestation. The oculomotor, trochlear, trigeminal, abducens, and facial nerves are myelinated by 26 to 28 weeks with the vestibular nerve being myelinated by 24-26 weeks following

conception. The olfactory and auditory nerves are not myelinated until term, and the optic nerve myelinates by 37 to 38 weeks following conception (Larroche, 1977).

In the cerebral peduncles, the medial and lateral lemnisci (carrying secondary and tertiary auditory fibers) are myelinated by 28 weeks. The inferior colliculus (receiving auditory fibers) is myelinated by 24 weeks according to Gilles et al. (1983) and 28 weeks according to Larroche (1966). The superior cerebellar peduncle (containing fibers interconnecting the cerebrum, brainstem, and spinal cord) is myelinated by 32 weeks following conception (Larroche, 1977); however, Gilles et al. estimated it may be myelinated as early as 26 weeks following conception. The superior colliculus (which receives spinotectal fibers from the ascending sensory tract, including fibers from the retina, cerebral cortex, inferior colliculus, hypothalamus, and substantia nigra) myelinates by 36 weeks (Larroche, 1977).

In the forebrain, none of the major structures are myelinated until 28 weeks and most not until later. Of particular interest are the optic and acoustical radiations, which are not myelinated until term.

Electrical Activity Changes in the Brain

The development of the brain is also reflected in changes in the electroencephalogram (EEG). It is assumed that the developmental processes of dendritic arborization and formation of synapses in the cortex

are structural correlates for developmental changes in the EEG (Haas & Prechtl, 1977). The sum of excitatory and inhibitory postsynaptic potentials is recorded by the EEG; therefore, the development of a spontaneous EEG and evoked response reflects the development of dendrites, dendritic spines, and dendritic synapses (Schulte, 1982). Evoked potentials will be discussed under evidence for sensory responsiveness.

Prior to 28 weeks' postconceptional age, the EEG allows for no clear discrimination between wakeful and sleeping states or different phases of sleep (Schulte, 1982). However, after that time EEG interpretation must be made with the knowledge of sleep state as changes in state are becoming apparent and are reflected in the EEG. Hrbek, Karlberg, and Olsson (1973) found that sensory responsiveness varied with state when regular periods of sleep emerged around 32 weeks' postconceptional age. However, it is not until 35-37 weeks' postconceptional age that state organization begins to be recognizable clinically, and it is not until term that states are fairly organized and stable (Parmelee & Stern, 1972; Parmelee, Wenner, Akiyama, Schultz, & Stern, 1967). Active sleep is characterized by body movement, rapid eye movements, irregular heart rate and respirations. At 30 weeks' postconceptional age, during active sleep there are slow, high-amplitude delta waves. With increasing age, the slow waves disappear, and by term a continuous pattern of 5 to 8 cycles per second waves dominates. The EEG allows a reasonable estimation of gestational age except that at-risk preterm infants (considered

to be at risk because of problems which occurred during pregnancy and/or during the perinatal period) have shown "age-inadequate" patterns; that is, the tracings have some patterns like those of a younger infant (Haas & Prechtl, 1977).

To summarize, it appears that the development of the central nervous system prior to 40 weeks is one of continuing change and increasing complexity. By the period of interest for this study, 25 to 40 weeks' postconceptional age, dorsal and ventral induction, proliferation, and migration are completed. Dendritic and axonal growth are already underway and continue at a rapid rate during weeks 25 to 40 following conception. Myelination continues, and with increasing age more areas of the nervous system are myelinated, increasing transmission rates and enabling neurons to handle repetitive firing and resist fatigue. Components of the vestibular system are myelinated early (24-26 weeks), perhaps making this system the most advanced along with the somatosensory system. The auditory system also has components which are myelinated by 24-28 weeks; however, the acoustical radiations and the auditory nerve are not myelinated until around 40 weeks' postconceptional age. The visual system is the last sensory system to myelinate at about 36-40 weeks. This progressive development of the brain is reflected in the electroencephalogram and provides a reasonable estimation of gestational age except for preterm infants who have been ill and may have patterns more like that of a younger infant.

Behavioral Development Prior to 40 Weeks' Postconceptional Age

Ultrasound Examinations

In addition to information about anatomical and physiological changes in the nervous system, there are also studies which document changes in behavior during early development. In this section, which reviews studies of both fetal and neonatal behavior prior to 40 weeks' postconceptional age, attempts are made to relate the previously discussed anatomical changes to observed behaviors.

For the purposes of this paper, "age" refers to the number of weeks following conception whether the term "gestational age" or "postconceptional age" is used. "Fetal" refers to infants in utero; "neonatal" refers to infants after birth. Unless the term "fetal" is used, the author is referring to neonates.

Ultrasound examination provided the earliest information regarding fetal movement. At 6 to 7 weeks' postconception, smooth vermicular (worm-like) movements have been noted (Ianniruberto & Tajani, 1981). These movements occurred at a time marked by the formation of the major structures of the brain (ventral induction) and synapse formation (Volpe, 1981). By 8 weeks, both rapid and irregular vermicular movements and quick flexion and extension movements of the trunk with slight movements of the limb were found. By 10 weeks, vermicular movements ceased and extension movements involved the lower and upper limbs (de Vries, Visser, & Prechtl, 1982; Ianniruberto & Tajani, 1981). By

12-13 weeks startle movements occurred and single isolated movements of a single limb were seen. Opening and closing of the hands, tongue protrusion, and "breathing" occurred at 13 to 14 weeks' postconceptional age. Further, extension and crossing of the lower limbs, plus exploration of placental surfaces by the hands, were seen by 13 to 14 weeks. These movements of the extremities occurred at a known period of proliferation and increasing density of axodendritic synapses. The fetus was observed to have fingers in the mouth and sucking by 15 weeks. By 15 weeks, too, startles, whole body movements, hiccups, breathing, isolated arm or leg movement, isolated retroflexion, antiflexion and rotation of the head, jaw movement, neck, swallow and hand-to-face activities were seen (de Vries et al., 1981). Good coordination of limb movements was documented by 16 weeks with the fetal head and feet pushing against the opposite uterine wall. Direct external pressure produced an associated response of the limbs at 19 weeks. Midgestation, or 20 weeks, coincided with isolated segmental movements of fingers, foot, eyelids, and mouth with jerking motion ceasing (Ianniruberto & Tajani, 1981).

As previously noted, the 18-24 week period was associated with the phase of maximum dendritic differentiation. Since myelination had just begun in the nervous system, this segmental type of movement demonstrated that myelination was not necessary for certain movements. By 24 to 25 weeks, the head rotated in response to mechanical stimulation and startles

became rare. At the point of potential viability, 26-28 weeks' postconceptional age, a sound stimulus produced a startle and increased heart rate; and habituation occurred if the stimulus was repeated (Ianniruberto & Tajani, 1981). Birnholz and Benacerraf (1983) demonstrated blink responses in fetuses to vibroacoustic stimulation provided by a stimulator placed on the maternal abdomen; eye blinks were noted by ultrasound examinations as early as 24 weeks and were consistently noted by 28 weeks.

Observations of Infants Born Prematurely

There is a paucity of information about developmental changes in the behaviors of infants born prematurely. However, in the 1950s Gesell observed infants born prematurely and recorded their changes in behavior from 28 to 38 postconceptional weeks. French neurologist Saint-Anne Dargassies also noted changes she observed in infants born prematurely from 20 to 41 weeks following conception. Both of these physicians talked mainly in terms of the unfolding maturation of a given infant. Obviously, from the photographs accompanying the discussion, the infants studied were not those on assisted ventilation or other forms of respiratory support. Therefore, these observed changes reflect those of infants able to survive without considerable interventions. A summary of their observations follows.

Infants of 20 to 28 weeks' postconceptional age. Infants of 20 weeks

showed no spontaneous movements, presumably because of their profound compromise resulting from a forced extrauterine existence (Saint-Anne Dargassies, 1977). Further, Dargassies found that drooling, palmar grasp, and the Moro reflexes existed at 22 weeks but were incomplete, lacking many of the components of the response elicited in the full-term infant. While spontaneous movements were absent, tactile stimulation produced movement of the entire upper limb. By 24 weeks Dargassies was able to observe some spontaneous movement, even though reported as slow and poor in quality. At this time, it was also noted that the infant maintained a localized withdrawal of the stimulated body part to pain; however, nonpainful tactile stimulation led to slow movements that became generalized to the whole body. It is at 24 weeks' postconceptional age that synapses are found in the cortical plate (Berry, 1980). Further, sensory fibers are beginning to myelinate at this time. Dendrites are also ramifying in the molecular layer of the cerebellum (Berry, 1980). Dreyfus-Brisac (1968) observed that the 24-27 weeks' postconceptional age infant had almost continual movement of all four extremities. At this time, the most differentiated (specialized) area in the motor cortex corresponds to the trunk (Larroche, 1977).

Dargassies observed that spontaneous movements of the limbs were more frequent, less slow, and of longer duration at 26 weeks. It is at this time that the layers of the cortex are evident, and also axons are more frequently found in relation to neurons. Stimulation for rooting

produced a yawn. By 27 weeks' postconceptional age yawning was less frequent, and more opening and closing of the mouth was observed, as well as tongue protrusion. Activity of the upper limbs also was more frequent and of greater amplitude than in the lower limbs. Greater movement of the upper extremities may reflect the fact that myelination of the sensory tracts of the upper body occurs before the lower body.

Infants of 28 to 30 weeks' postconceptional age. During this period, a gradual improvement in the primary reflexes, as well as general muscle tone, was described. This improvement may reflect the increasing dendritic complexity and synapse formation, as well as myelination of the dentate, red nucleus, globus pallidus, and subthalamic nucleus. (The dentate nucleus is the largest and most laterally placed cerebellar nucleus that sends axons into the brainstem. Small cells within the nucleus project to the thalamus, and large cells project to the reticular formation. Axons from the cortical Purkinje cells converge on the lateral surface of the dentate nucleus. The red nucleus, located in the midbrain, projects to the cerebellum and receives input from the cerebral cortex. The globus pallidus is part of the extrapyramidal motor system and is considered part of the basal ganglia. It receives fibers from the precentral gyrus and certain areas of the prefrontal cortex. Efferent output goes to the thalamus. The subthalamic nucleus projects to the globus pallidus.) Further, the cerebellum is undergoing change as the somatic spines disappear and the trees develop secondary and tertiary spiny branchlets (Berry, 1980).

The infant is described as hypotonic (having little tone) at 28 weeks, more so in the upper extremity than the lower extremity, with spontaneous movements now occurring in the lower limbs. The greater hypotonicity in the upper limbs may reflect the earlier development of the area of the cortex involving the lower extremities. Dargassies (1977) also described fine movement, clonic spasms (alteration in contraction and relaxation of muscles), and startles.

Prechtl, Fargel, Weinmann, and Bakker (1979) observed infants of 28-36 weeks' postconceptional age from their birth until 40 weeks' postconceptional age. Infants of 28 weeks were described as having their eyes open for short periods of time up to 5 minutes. Interestingly, they observed no trend in the number of observed eye movements throughout the developmental course before term. They also observed a clear-cut dominant head position to the right side from 28 weeks on. Body postures lasted only briefly but increased in duration with increasing age. By 30 weeks, spontaneous body movement was more rapid and like a "tempest" of movement; however, hypotonia remained as intense in the upper limbs. At 30 weeks, Dargassies (1977) described the eyes as being open for the first time. The fact that the eyes remained open may reflect the increasing development of the visual cortex, which is in the middle of its major dendritic increase. In addition, cranial nerves that control eye movement are myelinated by this time.

Infants of 31 to 32 weeks' postconceptional age. At 32 weeks,

Dargassies (1977) described the infant as livelier and more active, with vigilance occurring spontaneously. The infant kept his/her eyes open and appeared receptive and ready to react. Doll's eye movements (movements of the eyes produced by rotation of the head) were clearly observed, and pupillary response to light was present but slow. The infant was observed to get his fingers to his mouth, coinciding with myelination of the rubrospinal tract that contains fibers controlling flexion of the hands. However, even though the behavioral capacities of the newborn increase during the period of myelination, there is no reason to regard the former as a direct consequence of the latter since impulse traffic starts in the axons during and before the development of myelin sheaths (Jacobson, 1970). Further, the infant of 32 weeks was able to change from a supine to a lateral position. There was greatly improved spontaneous motility, with the baby moving in the incubator by arching his back, pushing, and creeping. A quiet waking state could be distinguished from phases of motor activity.

Gesell (1952) described infants of 28-32 weeks as easily aroused with brief, mild activity but never fully aroused. Body movements were described as generally sporadic and confined to brief ripples of activity with minimal tone. He felt positive visual response was either scant or absent.

<u>Infants of 35 weeks' postconceptional age</u>. Neither Dargassies (1977) nor Gesell (1952) offered a description of the 33-34 week

postconceptional age infant. At 35 weeks, the walking reflex, although not sustained, was observed for the first time (Dargassies, 1977). The upper half of the body continued to be described as hypotonic; however, the lower half was now described as hypertonic. It was reported that the head hung when the infant was pulled to a sitting position. When held in a sitting position, however, the infant would raise his/her head before letting it fall. This continuing improved performance in head control could reflect the increasing development of the motor cortex and increasing myelination of spinal-midbrain tracts.

Infants of 36 weeks' postconceptional age. After 36 weeks, gross motor activity decreased. This decrease is felt to reflect maturation of inhibitory mechanisms (Prechtl et al., 1979). In addition, Prechtl et al. found that the short episodes with eyes open gradually disappeared and were replaced by continuous, longer periods with the eyes open (similar to fullterm infants).

Infants of 37 weeks' postconceptional age. All four limbs were flexed in the resting posture with hypertonia hampering spontaneous motility (Dargassies, 1977). All of the primary reflexes were fully elicited.

Infants of 41 weeks' postconceptional age. Dargassies (1977) compared the infant born at 41 weeks with the preterm infant who had matured to the age of 41 weeks. She concluded that both infants had perfect primary reflexes and muscle tone of excellent quality; however, the

preterm infant did not exhibit muscular hypertonia, just good muscle tone. When crying, the preterm infant's muscle tone was more equivalent to that of a fullterm infant. Passive tone of the preterm infant differed slightly, with the preterm infant's having wider angles, greater amplitude, and more varied motility. Dargassies (1977) pointed out that the physical environment, as well as the nutritional environment, was quite different for the two. She observed that the ex-premature infant weighed 2600 grams at best (at term) and walked on his/her tiptoes rather than in the plantigrade fashion of the term infant. She also felt that the premature infant at term was more excitable and restless with a shorter attention span. Thus, although Dargassies emphasized the inherent sequences of maturation of the nervous system, she questioned whether a term infant brought to term was the same as an infant born at term. Although claiming that their neurological capabilities were similar, she hypothesized that some of the differences might be due to the variance of physical housing (uterus versus incubator) or secondary to nutritional factors.

Others have found that preterm infants at term perform less well on standard neonatal exams. In one study utilizing the Brazelton Neonatal Behavioral Assessment Scale, normal fullterm infants were compared to 20 preterm infants at term who were without serious disorder and who were born at a mean gestational age of 33 weeks. Preterm infants had statistically lower scores on the hand-to-mouth activities and adjustment to visual stimuli (Paludetto et al., 1982). In a similar study, preterm infants born

at 29-35 weeks' gestation and tested at term showed significantly lower scores than fullterm infants on the orientation subscale of the Brazelton Neonatal Exam (Leijon, 1982). Preterm infants also had poorer scores than fullterm infants for habituation items, activity, peak of excitement, and hand-to-mouth activity. However, preterm infants scored higher than fullterm infants on orientation to sound (Leijon, 1982).

To summarize this section on behavioral observations, ultrasonic examinations provide evidence of the early activity and reflexive abilities of the fetus. They also provide evidence that the fetus can respond to sound as early as 24 weeks. The observations of Gesell (1952), Dargassies (1977), and Prechtl et al. (1979) provide descriptions of the behavior of infants born prior to term. Both ultrasound and the behavioral descriptions suggest that the fetus and infant gradually increase their activity through 36 weeks of postconceptional age and show decreased spontaneous activity after that. As the fetus/infant grows, reflexive behavior increases in strength. Eye-opening and eye movements are present early in life (26-28 weeks) but are more like those of the fullterm infant by 36 weeks. Hand-to-mouth activity appears early in gestation and increases in facility with age. The prematurely born infant, upon reaching term, is similar to the fullterm infant in some respects; however, he/she is also quite different. For example, performance on many of the Brazelton Neonatal Exam items differs from that of the fullterm infant (Divitto & Goldberg, 1979; Leijon, 1982; Paludetto et al., 1982).

Evidence for Sensory Responsiveness in Preterm Infants

Responsiveness to four types of sensory stimuli is reviewed: visual, auditory, tactile, and kinesthetic/vestibular. For each, three types of studies assessing sensory responsiveness are reviewed: those that assess responsiveness by behavioral change; those intervention studies that provide the infant with a given type of sensory stimulation; and those that assess responsiveness by evoked potential. Each such type of study can provide evidence of responsivity. Changes in behavioral responses to a given stimulus in comparison to no stimulation conditions suggest that the infant is responding. Intervention studies offer indirect evidence of responsiveness by showing improved performance on developmental exams and/or greater weight gain for those infants receiving stimulation. Finally, the evoked potential offers evidence that the nervous system is responding to a given stimulus. Evoked potentials consist of a series of positive and negative peaks lasting for one-half second which occur in response to external stimuli. Medium latency components of the evoked potentials (about 100 msec) probably represent activity within a given primary sensory system in the cortex, while later positive or negative peaks (latencies about 200 msec) appear to be due to nonspecific or extra-primary sensory systems (Bronson, 1982). The major differences found between preterm and fullterm responses lie primarily in the latencies of the various components (Schulte, Stennert, Wellbrand, Eichorn, & Lenard, 1977). The amplitude of evoked potentials is smaller in active sleep than

in quiet sleep or wakefulness, just as in adults (Schulte, 1982). With increasing development, the latency of responsiveness decreases and the threshold of responsiveness also decreases.

Response to Visual Stimulation

Visual evoked responses (VER) have been used to demonstrate the intactness of the central nervous system in infants from as early as 24 weeks' postconceptional age. Hrbek (1973) found that after 27 weeks' postconceptional age the peak of a slow negative wave separated into distinctive deflections labeled II and III waves; by 30 weeks it was possible to distinguish a peak IV wave indicating activity in the extraprimary sensory system. Medium latency effects, suggesting activity induced in the occipital cortex, do not appear until around term (Bronson, 1982). In addition, the medium latency component quickly wanes with stimulation rates of as little as once per second (Bronson, 1982). These developmental changes in evoked potentials appear to reflect changes in the axonal and dendritic complexity and possibly myelination of the central nervous system. The visual cortex undergoes maximal dendritic increases during 24 to 32 weeks' postconceptional age. However, it is not until 36 weeks' postconceptional age that the optic chiasm is myelinated and not until term that the optic radiations are myelinated.

Evidence that the extrauterine environment might be detrimental to the developing visual system was found by Schulte et al. (1977), who compared the VER development of infants of 31 weeks' postconceptional age

with infants of 33 weeks' postconceptional age. All infants were tested at 33, 37, and 40 weeks' postconceptional age. Between 33-37 weeks' postconceptional age the VER changed from a negative double peak pattern to a biphasic/negative potential pattern for infants who had been born at 33 weeks' postconceptional age (Schulte et al., 1977). However, infants born prior to 31 weeks' postconceptional age, and therefore with longer extrauterine experience, showed these changes at later conceptional ages; and the VER was less complete at 40 weeks' postconceptional age than for infants born at 33 weeks. Since all these infants had few medical complications, the investigators speculated that the neonatal environment might be exerting an influence on the VER; the rapid development of dendrites, dendritic spines, and synapses occurring in the visual cortex between 30 and 36 weeks (Purpura, 1975) were probably affected (Schulte et al., 1977). These findings are consistent with other investigators' findings of deficits in visual attention and performance during the first year of life in infants born prematurely (Rose, 1981; Sigman & Beckwith, 1980).

The comparison of the performance of normal fullterm and low-risk preterm infants on visual function tests at 40 weeks' postconceptional age revealed significant differences in pattern preference and visual acuity (Morante, Dubowitz, Levene, & Dubowitz, 1982). Similarly, visual following and auditory orienting behavior at 40 weeks' postconceptional age was found to be significantly poorer for infants born prematurely. Full-

term infants demonstrated consistently good performance on the Brazelton Neonatal Exam orienting items in comparison to a high incidence of poor or absent orienting behavior in preterm infants (Kurtzberg et al., 1979). Further evidence for the effect of early environment on visual development is found in the development of amblyopia in fullterm infants. If the eyes are unable to produce two innervation patterns which can be fused by neural mechanisms as in squint or severe astigmatism, the innervation pattern of one eye is suppressed. If this suppression of afferent neural activity from one eye occurs during infancy or early childhood, a permanent amblyopia will result (Lou, 1982).

In terms of behavioral responsiveness, there is evidence in several studies that the preterm infant responds to visual stimuli. Preterm infants born at a mean gestational age of 29 weeks who suffered a minimum of complications were found to fixate on patterned stimuli in visual preference tests as early as 30 weeks' postconceptional age (Hack, Muszynski, & Miranda, 1981). In addition, soon after 30 weeks' postconceptional age, the infant discriminated a patch of gray from a patch of alternating black and white stripes at a distance of 14 inches (Miranda & Hack, 1979). Infants of 35 weeks' postconceptional age appeared in two ways to respond similarly to term infants. They discriminated between patterns differing mainly in brightness contrast and in the size of pattern elements (Miranda, 1970).

Tests of visual responsiveness at term and beyond add to our

understanding of the level of visual responsiveness of term infants and prematurely born infants. At birth, fullterm infants have been noted to turn their head and eyes significantly more to a face-like stimulus and follow such a face-like stimulus in preference to an equally complex and bright stimulus consisting of the same facial features in different arrangement (Goren, Sarty, & Wu, 1975). Fullterm infants have been noted to show greater visual interest in patterns than colors, and particularly in patterns similar to the human face (Fantz, 1963). Both prematurely born and fullterm infants, when tested at 5 to 25 weeks following birth, attended longer to patterns with more elements, angles, and contours (Fantz & Fagan, 1975), suggesting that both prematurely born infants at term and fullterm infants prefer similar patterned stimuli. In another study, visual responsiveness of low-medical-risk preterm infants at term and fullterm infants was compared by presenting either red or green three-dimensional, lighted, translucent, plastic boxes for the infants to view. They found that the fullterm group responded more quickly and took less time to reach the response decrement criterion than the preterm group (Friedman, Jacobs, & Werthmann, 1981), suggesting that preterm infants were less advanced developmentally in spite of the equal age. In addition, these findings suggest that the preterm infant's extra time outside the uterus offered no advantage in terms of visual function. There are no studies of responsiveness of preterm infants to facial visual stimuli.

There is only one report from an intervention study of a group of infants receiving visual stimulation only. They were exposed to colorful decals, a mobile, and pictures on the outside of the isolette. In a test of visual attention at the time of discharge, these infants looked significantly less at the visual stimuli than did the control infants, who did not receive additional visual stimulation. The decreased viewing time was felt to suggest greater ability to discriminate and habituate to visual stimuli (McNichol, 1973).

Response to Tactile Stimulation

Hrbek et al. (1973) demonstrated a changing pattern of somatosensory evoked response (SER) in preterm infants which began at 26 weeks as a large, slow, negative deflection thought to be an electrical response of very poorly developed and differentiated cortical cells. At 29 weeks, a smaller negative peak was followed by a smaller positive component, suggesting increased development of the central nervous system. As previously noted, sensory tracts carrying fibers from the brainstem to the spinal cord are myelinated by this time, and fibers connecting the cerebrum with the midbrain and spinal cord are myelinated by 32 weeks' postconceptional age.

Evidence of behavioral responsiveness is found in early reflexive responsiveness to tactile stimulation. Aborted fetuses turn away from light touch to the lips as early as 7 1/2 weeks' postconceptional age (Humphrey, 1978). As previously cited, ultrasound examination has

revealed limb response to direct external pressure at 19 weeks (Ianniruberto & Tajani, 1981). The observations of Gesell (1952) and Dargassies (1977) document the ability of even extremely immature preterm infants to respond reflexively to tactile stimulation. However, there are no studies which have examined the preterm's responsiveness to tactile stimulation of a social nature (e.g., stroking by hand) prior to 38 weeks' postconceptional age. Thus, there exists a rather large gap in our knowledge of the tactile responsiveness of infants born considerably before 37 weeks.

Comparing behavioral responsiveness to tactile stimulation of infants who were born prematurely and assessed at term to that of infants born at term has yielded conflicting data. Rose, Schmidt, and Bridger (1976) compared the behavioral responsiveness of preterm infants with a mean gestational age of 32 weeks (tested at 38.5 weeks) to term infants tested at 40 weeks using a stimulus of stroking with a plastic filament. Term infants showed a behavioral response of increased limb movement (greater than the nonstimulus condition) and a cardiac response of acceleration, while preterm infants responded with fewer limb movements and showed no cardiac response. In a similar study, however, preterm infants born at 33 weeks' postconceptional age and tested at 37.4 weeks showed not only increased limb movement, but cardiac acceleration as well, to being stroked with a plastic filament; their responsiveness in these ways did not differ from that of fullterm infants (Field, Dempsey,

Hatch, Ting, & Clifton, 1979). During habituation trials, the term infants also showed decreased responsiveness across trials, both decreased limb movement and lower heart rates. Preterm infants showed similar decreased limb movement but continued to respond with increased heart rate (Field et al., 1979). Measuring quickness of response (latency), initial responsiveness, amount of response decrement, and time to response decrement using a plastic filament stroking the cheek, Friedman et al. (1981) found no differences between term and preterm infants born at 33.5 weeks and tested at 40 weeks.

Thus, three studies (Field et al., 1979; Friedman et al., 1981; Rose et al., 1976) confirm the preterm infant's ability to respond at term in a similar manner to fullterm infants, suggesting that early birth may not alter the infant's responsiveness to tactile stimulation. It should be noted that the preterm infants in these studies were appropriately grown and did not suffer complications often associated with prematurity. However, the finding that preterm infants continued to respond with increased heart rate during habituation trials (Field et al., 1979) suggests that preterm infants were unable to habituate and therefore differed from the fullterm infants, who did habituate.

Less direct information about responsiveness to tactile stimulation can be found in the many intervention studies that have employed tactile stimulation of stroking and massaging. Intervention programs have consisted of rubbing the preterm infant's back, arms, and neck, or stroking

and flexing the arms and legs for 5 to 7.5 minutes per hour for 10 days from 28 to 37 weeks' postconceptional age. In various studies, tactile stimulation has been related to increased weight gain (Powell, 1974; Scarr-Salapatek & Williams, 1973; Solkoff, Yaffe, Weintraub, & Blase, 1969; White & Labarba, 1976), decreased crying, increased activity (Solkoff et al., 1969), higher scores on the Bayley Scales of Infant Development (Powell, 1974; Scarr-Salapatek & Williams, 1973; Solkoff et al., 1969), and more positive changes on the Brazelton Neonatal Exam (Solkoff & Matuszak, 1975). Other studies have not found increased weight gain (Hasselmeyer, 1964; Kramer, Chamorro, Green, & Knudtson, 1975; Solkoff & Matuszak, 1975). It is noteworthy that the studies finding no difference in weight gain began their stimulation programs a week or more after birth, whereas those finding increased weight gain began shortly after birth. The importance of tactile stimulation for growth has been illustrated dramatically in experiments with rat pups. Pups removed from the mother demonstrated significant drops in growth hormone and subsequent decreased rates of growth (Schanberg & Kuhn, 1980). However, when tactile stimulation similar to that provided by the mother was provided the pups, there were no drops in growth hormone and growth was normal.

In intervention studies including measures of cognitive and social development, infants receiving additional tactile stimulation performed better (Powell, 1974; Solkoff & Matuszak, 1975; Solkoff et al., 1969). For

example, Powell found that additional handling during hospitalization was associated with more optimal 4-month mental Bayley scores (MDI) and 6-month motor scores (PDI). Although these intervention studies suggest that the preterm infant responds to tactile stimulation, the nature of the response remains unclear.

Response to Auditory Stimulation

Development of the auditory system occurs fairly early in gestation. The membranous labyrinth of the inner ear reaches adult configuration by the early part of the 3rd month, and the inner ear shows complete maturation of the sensory and supporting cells in the cochlea by the 5th month of gestation. The inner ear is the only sense organ to reach full adult size and differentiation by fetal midterm (Northern & Downs, 1978). Elliot and Elliot (1964) confirmed that the human cochlea had normal adult function after 20 weeks of gestation. However, Nakai (1970) concluded that the organ of Corti in the 6-month fetus does not carry out auditory function because auditory function does not begin before the pillars separate to form the tunnel of Corti and the arrival of the efferent nerve endings. In terms of the middle ear, the incus and malleus have cartilaginous structure similar to the adult's by 8.5 weeks. The stapes grows as a cartilaginous structure until 15 weeks' gestation, when it starts to ossify, and is nearly complete by the 32nd week. By the 30th week the tympanum proper is almost complete (Northern & Downs, 1978).

As with other evoked potentials, the auditory brainstem response (ABR) has been traced and the latency of responsiveness found to decrease with increasing age. Each wave is thought to originate from a fairly specific portion of the central auditory pathways (Weber, 1979). Wave I of the ABR originates in the cochlear portion of the auditory nerve and is an index of peripheral transmission. Wave II arises from the cochlear nucleus of the medulla. Wave III originates in the superior olivary nucleus where second-order neurons terminate and is the first structure that receives fibers from both ears. Wave IV originates in the lateral lemniscus, which carries nerves to the inferior colliculus at the level of the midbrain represented by Wave V. Waves VI and VII are thought to arise in the thalamic and thalamocortical projections, respectively (Weber, 1979). Nerve conduction through the auditory system is at least partially dependent on myelination; therefore, factors that affect myelination may affect the ABR. Changes in central conduction could involve nerve conduction velocity associated with myelination and/or changes in synaptic efficiency at various nuclei of the auditory pathway (Starr, Amlie, Martin, & Saunders, 1977).

The auditory brainstem response (ABR) has been recorded in infants as young as 25 weeks' postconceptional age if the stimulus is sufficiently intense (75 db) (Starr et al., 1977). Thus, some investigators conclude that evidence from the ABR studies suggests that the fetus can hear 12-16 weeks before usual birth (Buckwald, 1981; Saunders & Bock, 1978). There

is a rapid decrease in latency for all waves from 28-36 weeks and smaller decreases from 36-44 postconceptional weeks (Schulman-Galambos & Galambos, 1975; Starr et al., 1977). Graziani, Katz, Cracco, and Weitzman (1974) described an increasingly mature ABR from 34-36 weeks with the ABR becoming similar to that of term infants by 36 weeks. Parmelee (1981) described a gradual decrease with increasing age in the threshold of responsiveness and fatiguability to repeated stimuli. Auditory function, however, has not been found to be completely developed at term (Starr et al., 1977). Peripheral transmission (latency to Wave I) decreases with gestational age, and the central conduction time continues to decrease throughout the first year of life (Starr et al., 1977). With insult to the central nervous system, there is an increase in latency which decreases with recovery (Kileny, Connelly, & Robertson, 1980).

In terms of behavioral responsiveness, some investigators have found that the 26-week fetus responds with increased heart rate to pure tone stimuli sounded close to the mother's abdomen (Johansson, Wedenberg, & Westin, 1964; Wedenberg, 1965). However, Bench and Vass (1970) were unable to obtain fetal heart responses to 500-4000 Hz tone at 100 dB in 20 subjects who were of later gestation than 26 weeks. This latter finding contrasts sharply with the ultrasound findings discussed earlier in this paper which demonstrated fetal startles and cardiac acceleration at 26 to 28 weeks' postconceptional age to a sound stimulus presented near the mother's abdomen (Ianniruberto & Tajani, 1981). Further,

Birnholz and Benacerraf (1983) demonstrated fetal eye blinks as early as 24 weeks in response to vibroacoustic stimulation provided by a stimulator placed on the maternal abdomen. In addition, a study of prematurely born infants showed that 29% of the infants who were less than 30 weeks' postconceptional age responded to clicks with increased motor activity and 5% with blinks; motor responses were found to decrease while blinks increased with increasing age (Monod & Garma, 1971).

Kearsley (1973) found that unexpected noise of 70 dB which reached maximal intensity in a few msec caused closing of the eyes, a startle, and increased heart rate in fullterm infants. However, if the sound reached maximum intensity in 2 seconds, the infant's eyes opened with eye shifting and the heart rate decreased, suggesting that sudden unexpected noise produced an alerting response.

Responsiveness to auditory stimulation at term in preterm and fullterm infants was found to be related to the state of the infant. Bench and Parker (1971) found that the magnitude of the response to sound was influenced by the state of the preterm and fullterm infants tested at 41 weeks' postconceptional age before stimulation. The lower the state of arousal (nearer to deep sleep), the greater the increase in activity to stimulation; the higher (closer to awake) the initial state, the greater the decrease in activity.

Responsiveness to the human voice has also been studied in preterm infants. Preterm infants born at 28-32 weeks who had been exposed to a

taped recording of their mother's voice from birth to 36 weeks showed a greater decrease in heart rate to their mother's voice during an arousal state than preterm infants who had not been exposed to recordings of their mother's voice (Segall, 1972).

There is some information about how the infant born prematurely compares with the infant born at term in terms of auditory responsiveness when both are tested at 40 weeks' postconceptional age. Fullterm infants have been found to be better sound detectors in that they respond with eye-blinks or startles to a sound (100 broad spectrum noise band) stimulus more often during active sleep than infants born prematurely (Bench & Parker, 1971). Further, fullterm infants were noted to habituate faster than preterm infants to a patterned auditory signal (Eisenberg, Cousin, & Rupp, 1966). When fullterm infants were compared with low-risk, preterm infants at term on responsiveness to pure tone, the fullterm infants were "somewhat more responsive" (Friedman et al., 1981).

Intervention studies add to our information on auditory responsiveness. Intervention studies have looked specifically at auditory stimulation and have found positive effects of extra auditory stimulation. Preterm infants exposed to a taped female voice from birth to 36 weeks showed increased motor maturation on the Graham Rosenblith test at 37 weeks (Katz, 1971). Further, infants who had heard a recording of their mother's voice played for 30 minutes per day from birth to 36 weeks showed greater acceleration in heart rate to white noise and significantly

greater decrease in heart rate to their mother's voice during an arousal state than control infants (Segall, 1972). In another study of preterm infants of 26 to 33 weeks' postconceptional age, 52 infants were exposed to ambient noise in the nursery, 50 to taped mother's voice, and 51 to an orchestral arrangement of Brahm's Lullaby beginning on the 5th day of life for 5 minutes at 2-hour intervals six times daily. Limb activity was measured when the infants reached a minimum of 1800 grams. No differences in limb activity were found for any of the infants; however, infants hearing music reached the weight of 1800 grams by an average of 35 days as opposed to 40 and 42 days for the taped voice and ambient noise group. Unfortunately, no information was given regarding whether or not these infants were all fed comparable calories (Chapman, 1979).

Kinesthetic-Vestibular Responsiveness

Korner (1980) has speculated that the vestibular system may be one of the earliest functionally maturing sensory systems in humans. Since the vestibular system appears to be the earliest functioning sensory system, it has the most opportunity to be affected by early birth. The inner ear is adult size by the middle of gestation. The vestibular nerve and other vestibular pathways are myelinated by 24-26 weeks, and the vestibular portion of the cerebellum, the floculonodular lobe, the uvula of the inferior vermis and fastigial nuclei are myelinated by 32 weeks (Barr, 1979).

No studies have directly evaluated the processing of proprioceptive

stimuli prior to 40 weeks' postconceptional age. At about 33 weeks, however, the appearance of nystagmus (constant, involuntary, cyclical movement of the eyeball) suggests vestibular functioning (Pendleton & Paine, 1961). In fullterm infants, movement into an upright position enhanced visual attention to a moving black line whereas a stationary upright position did not (Gregg, Haffner, & Korner, 1976). Fullterm infants brought to the shoulder became alert and scanned the environment (Korner & Grobstein, 1966). Visual scanning was found to be significantly better when the infant was held to the shoulder as compared to lying down (Fredrickson & Brown, 1975). Further, vestibular-proprioceptive stimulation was also found to be soothing and effective in reducing crying (Korner & Thoman, 1972).

Even though the preterm infant's response to proprioceptive-vestibular stimulation is not well established, intervention provides information regarding the effects of providing increased motion to premature infants. As with tactile stimulation, it can be inferred that the infant does respond to vestibular stimulation because of the changes which appear to occur with provision of kinesthetic and vestibular stimulation. A number of these intervention studies were based on the reasoning that since kinesthetic stimulation experienced *in utero* is much greater than that experienced by the preterm infant, kinesthetic stimulation should be artificially induced for the preterm infant. Regular rocking motion produced by mechanical movement of the preterm infant's bed at regular intervals

has been found to decrease apneic episodes (Kattwinkel, Hearman, Fanaroff, Katona, & Klaus, 1975; Korner, 1980; Korner, Kraemer, Haffner, & Casper, 1975). The continuous irregular oscillation of the water bed may have provided afferent input to the respiratory center, thereby decreasing the apnea (Korner, 1980). Oscillating water beds, therefore, have been a frequent intervention for preterm infants. Neal (1968) found that preterm infants of 28-32 weeks who had experienced rocking hammocks for 4-8 weeks, beginning at the 5th day of life, showed increased weight gain and increased visual orientation but no differences in tactile and auditory responsiveness when compared to preterm infants who had not received this stimulation. Evidence for altered sleep patterns came from an intervention study which involved 12 preterm infants with a mean postconceptional age of 32.7 weeks who were without major medical complications. The intervention group, cared for on water beds, showed more quiet sleep, fewer jerky movements, and less fuss and cry episodes than a comparison group (Edelman, Kraemer, & Korner, 1982).

Other investigators have combined rocking with other sensory stimuli. Auditory stimuli in the form of a heart beat recording combined with a rocking bed for 15 minutes per hour during the 33rd and 34th weeks for infants born between 28-32 weeks of gestation led to longer duration of quiet sleep, less activity when awake, greater maturity, and greater weight gain (Bernard, 1972). Kramer and Pierpont (1976) not only found increased weight gain but increased head circumference as well when they

used rocking water beds and a taped heartbeat beginning between 2 and 7 days after admission for preterm infants and extending for the duration of stay in the incubator. Unfortunately, because of the combination of stimuli in these studies it is not clear whether the changes seen were due to auditory stimulation, kinesthetic-vestibular stimulation, or the combination of the two.

Stimulation in Multiple Sensory Modes

Many intervention studies have provided various types of stimulation in combination. These combinations make it difficult to tease apart the effect of a single variable. As might be expected, a variety of beneficial results have been reported in the different studies--increased quiescence, increased weight gain, increased formula intake, decreased feeding requirement, more optimal Bayley Scales of Infant Development scores, and increased maturational development. As one example, a recent study employed visual, tactile, kinesthetic, and auditory stimulation and found that treated infants performed better on the Brazelton Neonatal Exam and had higher scores on the Bayley Scales than the control group (Leib, Benfield, & Guidubaldi, 1980), but no significant differences in weight gain were found. In another study, tactile and rocking stimulation resulted in greater weight gain, more optimal Bayley scores, and greater maturation as judged by reflex responses at 4 months of age (Rice, 1977). In still another study, combinations of visual, auditory, tactile, and kinesthetic stimulation were associated with more optimal Cattell scores at 1 year

(Scarr-Salapatek & Williams, 1973), suggesting that there are long-term effects of the additional stimulation to preterm infants. None of these studies, however, assessed directly the responsiveness of the preterm infant to combinations of sensory stimuli at the time the stimulation was provided.

One other study, however, has assessed directly the responsiveness of the preterm infant to stimulation in a combination of modalities; in an intervention study combining auditory, vestibular, and tactile stimulation, tactile responsivity was assessed with and without auditory stimulation as one measure of the effects of the intervention (Schmidt, Rose, & Bridger, 1980). Intervention involved a combination of tactile stimulation in the form of massage, vestibular stimulation in the form of rocking, and auditory stimulation in the form of talking. The intervention was initiated within 2 weeks of birth and performed daily five times a week with the average baby receiving 13 days of stimulation. Tactual responsiveness was compared for the preterm infants with and without intervention and fullterm infants. In the presence of auditory stimulation with a heartbeat sound, preterm infants who were not in the intervention group showed increased heart rate and spontaneous motor activity to tactile stimulation with a plastic filament, whereas without the heartbeat sound they did not respond. The preterm intervened infants and fullterm infants were responsive whether the background heartbeat sound was present or not.

Orienting and Defensive Responses to Sensory Stimuli

For the fullterm newborn, it has been proposed that there are basically two arousal systems which affect behavior differently: one reflected in the orienting response; the other in the defensive response. Sokolov (1963) hypothesized that the orienting response was part of a basic perceptual system geared toward the taking in and processing of information. The defensive response, in contrast, was related to the protective and information-limiting system. Consequently, the orienting response was viewed as being fundamental to more complex perceptual and cognitive processing (Sokolov, 1963). The characteristic orienting response in adults and older infants included a deceleration in heart rate which occurred quickly after presentation of a novel stimulus. The heart rate returned to normal as habituation occurred. The defensive response included heart rate acceleration and was evoked by high-intensity stimuli. The orienting response was evoked by novel stimuli below the intensity to evoke the defensive response and served to enhance the effects of stimulation. Further characteristics of the orienting response included dishabituation with stimulus change and deceleration of the heart rate at the offset of a sufficiently long stimulus (Berg, 1972, 1974).

Up until the 1970s it was felt that the fullterm newborn only showed a heart rate acceleration to stimulation and that there was little promise of the orienting response (heart rate deceleration) being elicited from the newborn (Graham & Jackson, 1970). It was felt that the neonate's lack

of experience with any form of sudden peripheral stimulation led to an interpretation of abrupt changes as aversive (Gary & Crowell, 1968). Following Graham and Jackson's review paper (1970) urging more careful research to identify an orienting response in the neonate, a flurry of studies did identify a heart rate deceleration response in the newborn, although it was felt to occur "only under the most optimal conditions" (Berg, 1974, p. 311). However, only 2 years later, Berg concluded, "On the basis of recent data it may be concluded that the newborn is indeed capable of a deceleratory response . . . and the direction of heart rate change may be as useful an index of orienting and defensive behavior in the newborn as older infants" (Adkinson & Berg, 1976, p. 47). Further, he concluded that there was no obvious developmental trend over the first few months in the ability to show a cardiac deceleratory response as had been thought earlier.

A variety of studies have demonstrated clearly that state is important in determining the nature of the fullterm infant's heart rate response to stimulation (Graham & Jackson, 1970). For example, between 2-8 weeks of life the same tactile stimulus produced acceleration during sleep and deceleration during an awake state. Presenting stimulation before the feeding period also seemed to favor the appearance of an orienting response (Pomerleau-Malcuit, Malcuit, & Clifton, 1975).

In addition, characteristics of the stimulus have been found to be important. Clarkson and Berg (1978) found that pulsed auditory stimuli

(more like speech) elicited heart rate deceleration while continuous auditory stimuli generally led to acceleration. The largest deceleration to pulsed stimuli was produced by the most spectrally complex stimulus (simulated speech) (Clarkson & Berg, 1978).

The orienting response has not been studied in the human fetus. However, as noted earlier in this paper, fetuses of 24 to 26 weeks have been noted to show heart rate acceleration in response to a tone sounded close to the maternal abdomen. Preterm infants (born "2 1/2 to 3 1/2 months early") demonstrated a startle accompanied by a pause in respiration and an increase in heart rate to either a light, tone, or electrical bell stimulus, suggesting a defensive response; with increasing age there was a gradual increase in the number of cases showing slowing of heart rate, suggesting an orienting response (Polikanina & Probatova, 1965). Infants born 1 1/2 months prior to term had more heart deceleration than acceleration in response to stimuli by 20 to 30 days of life (Polikanina & Probatova, 1965).

<u>Summary</u>

It seems clear that the preterm infant does respond to many modes of sensory stimulation prior to 40 weeks' postconceptional age. Evidence of the increasing ability to respond is found in studies of visual, somatosensory, and auditory evoked potentials which demonstrate responsiveness in the youngest of infants and decreased latency of responsiveness with increasing age. These findings suggest that the preterm infant can

respond to visual, auditory, and tactile stimulation and that the time to respond and the amount of stimulation needed to evoke a response decrease with increasing age.

Further, there is much evidence from intervention studies that suggests that preterm infants do respond in some way to sensory stimulation. Intervention studies have added to our understanding of sensory responsiveness by demonstrating differences in performances of preterm infants who receive special sensory stimulation and those who do not. Extra visual stimulation in the form of colorful decals, pictures, and a mobile was associated with greater ability to discriminate and to habituate to visual stimuli (McNichol, 1973). Planned tactile stimulation in the form of stroking or massage several times a day, particularly when started soon after birth, produced increased weight gain (Powell, 1974; Scarr-Salapatek & Williams, 1973; Solkoff et al., 1969; White & Labarba, 1976). Further, intervention with planned tactile stimulation also was associated with better performance on tests of cognitive and social development (Powell, 1974; Solkoff & Matuszak, 1975; Solkoff et al., 1969). Auditory stimulation provided by a taped female voice was associated with increased motor maturation on the Graham-Rosenblith tests at 37 weeks (Katz, 1971) and a more consistent decrease in heart rate to the mother's voice (Segall, 1972). The addition of planned vestibular/kinesthetic stimulation via rocking water beds was associated with increased weight gain and increased visual orientation (Bernard, 1972; Kramer & Pierpont,

1976; Neal, 1968). Even though these intervention studies do not delineate the specific response of the infant to a given stimulus, they do suggest that the infant is responding. Intervention studies, however, do not answer the question of the nature of the response or how responding changes with development.

The clearest developmental picture exists for visual stimulation. Preterm infants respond to visual stimuli as early as 30 weeks' post-conceptional age, showing increased attention and quicker response decrements to repeated stimulation with increasing age. The ability to fixate occurs by 29-30 weeks' postconceptional age, and visual discrimination occurs by 35 weeks. Still, it is not clear how or when the preterm infant responds to the human face. Fullterm newborns, however, appear to prefer the human face to scrambled face-like stimuli (Goren et al., 1975).

The developmental picture for tactile responsiveness is less clear. By term, the prematurely born infant may respond with increased body movement and increased heart rate to tactile stimulation administered with a plastic filament (Field et al., 1979; Friedman et al., 1981). However, infants born prematurely and tested at term showed less ability to habituate than term infants (Field et al., 1979).

For auditory behavioral responsiveness the developmental picture is also limited. Auditory stimulation in the form of a pure tone produced an increased heart rate, while clicks inconsistently produced motor activity in infants less than 30 weeks' postconceptional age. With

increasing age, motor activity decreased in response to the clicks, and eye blinks increased (Monod & Garmon, 1971). Premature infants tested at 36 weeks have also demonstrated cardiac deceleration to their mother's voice (Segall, 1972).

Another source of information about the development of responsiveness to sensory stimuli comes from studies comparing the performance of fullterm infants with preterm infants when both are 38 to 40 weeks' postconceptional age. It seems clear, for the most part, that the preterm infant at term performs differently than the fullterm infant when tested at 38 to 40 weeks' postconceptional age. In tests of visual responsiveness, fullterm infants responded more quickly and took less time to reach the response decrement criterion than the preterm infants (Friedman et al., 1981). In regard to responsiveness to tactile stimulation, both preterm and fullterm infants showed cardiac acceleration and increased body movement over baseline measurements when stroked with a plastic filament (Field et al., 1979; Friedman et al., 1981); however, preterm infants showed less ability to habituate (Field et al., 1979). Using a similar design, Rose et al. (1976) found that preterm infants showed fewer limb movements than the fullterm infants and no cardiac response. In regard to responsiveness to auditory stimulation, fullterm infants have been noted to respond to a sound stimulus with eye blinks and startles more frequently than prematurely born infants (Bench & Parker, 1971). Further, fullterm infants were found to habituate to a patterned auditory signal

faster than preterm infants (Eisenberg et al., 1966). Prematurely born infants were also noted to be less responsive with less heart rate increase than fullterm infants (Friedman et al., 1981). There are no comparison studies for vestibular/kinesthetic stimuli.

A final question about the nature of responsiveness to sensory stimulation is how the infant responds to relevant social stimuli. Studies of the responsiveness of the preterm infant to stimuli produced by a human caretaker (such as facial expression, talking, touching, or rocking) are few in number. There are no such studies for visual, tactile, or vestibular/kinesthetic stimuli. As previously noted, preterm infants have shown cardiac deceleration to their mother's voice (Segall, 1972).

Finally, in regard to the orienting and defensive response, both preterm and fullterm infants seem capable of demonstrating these responses (Berg, 1974; Clarkson & Berg, 1978; Polikanina & Probatova, 1965). However, we know very little about the preterm infant since there is only one study which demonstrated that the likelihood of an orienting response or deceleration in heart rate increased with increasing age of the infant (Polikanina & Probatova, 1965).

Factors Altering the Sensory Responsiveness of the Preterm Infant

While advanced technology has made the survival of a very immature infant more likely, it has also meant exposure to a host of experiences quite unlike those of a fullterm infant. The world of the tiny preterm

infant is truly quite different than that of the fetus in utero. First of all, consider the physical environment. The preterm infant is usually subject to bright lights 24 hours per day and the high noise level of a busy intensive care nursery. Also, the preterm infant is cared for under a radiant heater with no clothing, or the infant is enclosed in an incubator. Further, the preterm infant is without the usual intrauterine kinesthetic stimulation. Preterm infants who suffer significant illness experience still further alterations in their environment. In the interest of preserving life, the infant is given drugs that may affect the developing nervous system. In addition, the infant undergoes painful or aversive procedures as part of the effort to maintain life. In spite of staff efforts, it is not uncommon for the infant to experience hypoxia (deficiency in oxygenation), which also may affect the developing nervous system. The tiny baby frequently receives inadequate nutrition because of the difficulties encountered in feeding an infant with an immature digestive tract. Finally, the infant is not cared for by parents but is cared for by strangers who often act upon the infant in ways not contingent upon the infant's behavior or in any way under the control of the infant.

This fourth section reviews the many factors which could be expected to alter the development of the preterm infant from the normative path of development. We already know from the previous sections that the infant born prematurely is often different from the fullterm infant when compared at 40-41 weeks following conception. In an attempt to disentangle the

effects of the host of possible factors, individual factors are examined here. In some cases, there is direct evidence for linking a specific factor to an alteration of the preterm infant's responsiveness. In other cases, there is indirect evidence which suggests that a particular factor could influence the preterm infant's development. Considered first are the possible effects of illness on the infant through pathological processes, through accompaniments to illness such as the drugs used to treat the illness, through interference with normal nutrition, or through the experiences of multiple aversive procedures. Second, evidence for the effects of the altered physical environment (including altered noise and light levels) are reviewed. Finally, evidence for the effects of variations from usual parenting are considered.

Effects of Illness

All very immature infants can be considered ill since they initially require intensive care. However, it is clear to any clinician, observer, or parent that there are vast differences in the care of these infants, depending on the degree of illness. Severity of illness has been difficult to assess, and investigators have tended to use their clinical judgment in labeling infants as mildly, moderately, or severely ill. Mildly ill generally refers to those infants who have a minimum of complications and do not require mechanical ventilation. Severely ill refers to those infants who require prolonged mechanical ventilation and experience other severe complications, e.g., bronchopulmonary dysplasia, patent ductus

arteriosus requiring chemical treatment or surgical ligation, and feeding difficulties. Moderately ill infants usually refers to infants falling somewhere between these two extremes.

Illness can have both direct and indirect effects on the infant. Evidence for the direct effects of illness on the body system will be considered first. The various complications of prematurity considered as illness have the potential to cause damage to the central and peripheral nervous systems. Oxygen deprivation, which can occur as a result of many of the complications of prematurity, is a major cause of damage to the nervous system. Even if the damage is temporary, hypoxic insult may decrease the infant's ability to react to stimuli.

Hypoxia has been associated with alteration in the numbers of axonal plexuses in the hippocampus (Purpura, 1975). Postmortem sections from the visual cortex of 10 preterm infants who had survived at least 3 weeks were compared with those of term infants born at the same postconceptional age. Neuronal development in the visual cortex of 4 of these preterm infants was abnormal. Many immature neurons were seen on neuronal counting and Golgi staining in 2 of the infants, 1 with bronchopulmonary dysplasia and 1 with a patent ductus arteriosus. The morphology of dendrites and spines was markedly abnormal in the 2 other infants, who also showed cerebral palsy and posthemorrhagic hydrocephalus (Takashima, Becker, & Chan, 1982). Similarly, alteration in development reflected in the EEG has been found to be associated with hypoxia. Infants

suffering severe hypoxia were found to have EEG development which was 2-3 weeks behind infants of similar age but without hypoxia (Karch et al., 1982). Haas and Prechtl (1977) also found that EEG patterns of infants at medical risk were less mature than infants of similar age not at risk.

Further evidence of neurological delay associated with degree of illness has been found by examining the sleep cycles of sick and well preterm infants. Ten infants of 30 to 40 weeks' postconceptional age with hyaline membrane disease (HMD) were found to have more active sleep and less quiet sleep (a less mature pattern) than premature infants of similar postconceptional age without medical complications (Holmes, Logan, Kirkpatrick, & Meyer, 1979). Once the infants with HMD were off the ventilator, there was fairly rapid progress toward a more mature sleep pattern. In a similar study of behavioral and EEG change, 52 preterm and fullterm infants requiring assisted ventilation and 24 preterm infants of 30-36 weeks' gestational age without complications were compared on spontaneous body motility, eye movements, and EEG patterns (Karch et al., 1982). The sleep cycles of preterm infants without mechanical ventilation were compared to low-risk preterm infants receiving mechanical ventilation and high-risk preterm infants and fullterm infants receiving mechanical ventilation. High-risk preterm infants showed a distinct reduction in periods of wakefulness and an increase in indeterminate sleep. The increase in indeterminate sleep was interpreted as a function of disturbance of the central nervous system (Karch et al., 1982). In addition, EEG

development was less advanced for infants of increased risk; 80% of the infants with retardation in EEG development had suffered severe hypoxia, suggesting dysfunction of the central nervous system (Karch et al., 1982).

Further evidence for an effect of illness on the nervous system was found in a study which compared four groups of infants differing in age and severity of medical complications on head-turning responses. Ill preterm infants showed the least head-turning response, tending to maintain their heads in the midline rather than turning to the right as most normal infants do after 35-36 weeks. Ill infants also scored the poorest on the traction or pull-to-sit response, suggesting decreased muscle tone and a delay in motor development (Fox & Lewis, 1982). Similarly, preterm infants (28-37 weeks at birth) with respiratory distress syndrome (RDS) were tested at irregular intervals and found to have poor muscle tone; they did not assume a head-right position even at 39 weeks, suggesting that motor development was affected by illness (Lewkowicz, Gardner, & Turkewitz, 1979).

Indirect effects of illness can occur because of the treatment process and prolonged hospitalization. Among the indirect effects of illness are those associated with the administration of drugs to treat the illness. Ill premature infants are often given drugs, and the long-term effects of these drugs are not always known. However, it is known that certain drugs have the potential to cause long-term effects in other species. For example, rat studies have shown that phenobarbital (commonly used to

treat seizures in humans) can destroy brain cells at the proliferative stage. Phenobarbital also has been shown to destroy cells already formed in the rat. In one study (Yanai & Bergman, 1981), Purkinje and granule cells of rats were decreased by one third, the density of cerebellar cells was also reduced, and the area of the hippocampal layers decreased 15 to 20%. In addition, a group of antibiotics commonly used in the treatment of neonatal infection (aminoglycosides) seems to have an effect on vestibular functioning and hearing in infants. In one study of preterm infants treated with gentamicin and kanamycin, significant delay in the development of head control during the first year of life was noted (Eviatar & Eviatar, 1982). These investigators concluded that the delay was related to abnormal vestibular function for these infants and that a combination of ototoxic drugs (gentamicin and amikacin or gentamicin and tobramycin) may have greater vestibular ototoxicity than when each drug is used alone (Eviatar & Eviatar, 1982).

Illness also poses problems of delivering sufficient nourishment to the infant. Immature infants frequently have difficulty tolerating oral feeds. Further, infants with disease conditions such as those interfering with normal respiration and oxygenation require more than the usual calories to grow. Consequently, many of the very-low-birthweight infants suffer a degree of malnutrition. Malnutrition has been found to affect normal brain growth and subsequent mental development both in animal and human models (Crnic, 1983; Winick, 1970, 1973; Winick & Rosso, 1969a, 1969b).

Animal models have been used to explore the effects of malnutrition. Rat pups, whose newborn state roughly corresponds to the end of the second trimester in humans, have often been used to examine the effects of pre- and postnatal nutritional deprivation (Leatherwood, 1978). Winick (1970) found that rat pups exposed to both pre- and postnatal nutritional deprivation had fewer brain cells than those with prenatal or postnatal deprivation alone. Malnutrition produced permanent deficits in the rat's body and brain weight, DNA, RNA, and protein (Crnic, 1983). Long-term effects of malnutrition on rats were reduced weight, length, and width of the cerebrum (Katz & Davies, 1983). Smart and Dobbing (1971) observed delays in the appearance of different motor skills of rat pups with a restricted diet; however, motor skills did eventually develop.

There are varying results concerning whether the effects of early malnutrition can be mitigated. Crnic (1983) found that a complex environment did not mitigate the reduced weight, DNA, RNA, and protein produced by malnutrition during the weaning of rats; however, the malnourished rats subsequently raised in an enriched environment were less emotionally reactive and showed improved passive-avoidance learning performance. In contrast, Katz and Davies (1983) found that malnourished rats who had suffered deficits in weight and size of the cerebrum and hippocampus, and who were subsequently reared in an enriched condition for 30 days, significantly increased the weight and size of their cerebrum with the greatest increase in thickness occurring in the occipital region.

However, the reduced hippocampal thickness caused by early malnutrition failed to be significantly altered by the differential housing. Further, it was found that the most pronounced effect of enriched housing was an increased thickness in the area of the occipital region (Katz & Davies, 1983).

Human studies of malnutrition have yielded similar results. Winick (1969b) reported that fullterm infants who died of food deprivation during the first year of life had a 15 to 20% reduction in the number of brain cells. Infants weighing less than 2000 grams at birth, who subsequently died of severe undernutrition during the first year of life, showed a 60% reduction in brain cells. In another study, severely malnourished children dying during the first year of life were noted to have a marked reduction in cell number in the cerebellum, cerebrum, and brainstem (Winick, 1970). The reduced number appears to be a result of reduced glial cell production, which probably has led to the observed myelin deficits noted in infants malnourished early in life (Chase, Welch, Dabiere, Vasan, & Butterfield, 1972). In malnourished infants a 19% decrease in total cerebral DNA and a 35% decrease in cerebellar DNA was found, suggesting reduced glial cell division (Chase et al., 1972). Malnourished children also have been noted to have impaired performance on developmental exams. Children who were less than 6 months old at the time of their admission for kwashiorkor have been noted to have consistent deficits on the Gesell developmental exam (Cravioto & Robles, 1965).

It is known that late prenatal and early postnatal brain growth involves important aspects of brain development, such as multiplication of glial cells (cells that support, protect, respond to injury, and provide myelination), growth in dendritic complexity, and establishment of synaptic connections (Brandt, 1976; Winick & Rosso, 1969a). The earliest period of brain growth involves an increase in neurons; by 18 to 20 weeks following conception all the neurons the individual will have are present. A second period of growth begins during the second half of pregnancy and continues during the first 2 years of life; glial cells increase during this growth period (Dobbing & Sands, 1971). Cerebellar growth spurts occur during the 30th week of gestation through the 1st year of life (Winick, 1970). Thus, the low-birthweight infant is born and suffers a variety of medical problems during a period of expected rapid brain growth. Some medical problems may directly affect brain development; others may interfere with appropriate nourishment and hence indirectly affect brain development. Undernutrition, which affects brain growth, would also be expected to affect the infant's ability to respond to sensory stimulation.

In addition to the effects of illness per se, drugs and malnutrition, there may also be psychological effects of the treatments of illness which affect the responsiveness of the infants. Sick infants are likely to experience repeated aversive procedures, e.g., various blood tests, the starting of intravenous infusions, suctioning, or chest physiotherapy. Some preterm infants have been noted to behave as if touching and handling were

highly aversive to them (Hertzog, 1979). Hertzog (1983) described a poignant case of a young child born prematurely who initially sought and then demanded to be hurt for the first 2 years of life. He theorized that her early life experiences, in combination with the reaction of the parents to early events and stresses, caused this abnormal behavior. There appear to be no other studies which have looked directly at the effects of aversive procedures on the subsequent behaviors of children born prematurely. However, one might expect that infants who undergo more aversive procedures (i.e., the sickest infants) might respond differently than those with fewer aversive procedures to sensory stimuli, particularly tactile stimulation.

The Physical Environment

The quite different physical environment experienced by premature infants during their hospital stay may affect development of sensory responsiveness. Some clinicians view special care nurseries as providing excessive stimulation; others have regarded the nursery as sensory depriving. Still others have suggested that there is an inappropriate pattern of stimulation rather than an inadequate amount of stimulation (Gottfried, Wallace-Lande, Sherman-Brown, King, & Coen, 1981; Lawson, Daum, & Turkewitz, 1979). Unfortunately, there is a paucity of data to support any of these positions. While it is relatively clear what infants are exposed to in a particular special care nursery, it is not clear how the infant responds to the nursery environment.

Considerable animal work has been done around the question of the effects of a stimulating versus a nonstimulating environment upon early development. The development of mammals is felt to be influenced strongly by the interaction of the animal with the immediate environment (Schanberg & Kuhn, 1980). Rats developing in an enriched environment have shown greater weight gain, increased thickness of cortex, increased glial cells, increased problem-solving ability, increased exploratory behavior, decreased emotional reactivity, and increased weight gain (Rosenzweig, Bennett, & Diamond, 1972; Schaefer, 1963; Weininger, 1956). Morphological consequences appear to be increased dendritic spines which lead to an increased number of synapses, consequently increasing the thickness of the cortex (Lou, 1982).

Animal models have not only shown acceleration of responsiveness with stimulation but deceleration or delay with deprivation (Gottlieb, 1971). Lack of sensory stimulation during brain development appears to impair proper developmental changes in nucleic acids, adenosine triphosphates, and other enzymes in the brain. Sensory deprivation experiments have shown that the development of adenosine triphosphatase concentration is dependent on stimulation, especially in structures that receive afferent input directly from receptors. Proper development of neural membrane function appears to be critically dependent on stimulation (Lou, 1982). (Adenosine triphosphate is the main energy-rich compound in the body and is directly related to transmission of energy from

the citric acid cycle to energy-requiring processes, e.g., membrane functions in the brain. Adenosine triphosphatase is an hydrolytic enzyme that releases energy for such functions.)

In considering the effects of early stimulation, the possibility of sensitive periods must be entertained. Sensitive periods are time periods when the organism seems particularly sensitive to the effects of the environment. There are numerous examples from the animal literature which suggest that exposure to stimulation during certain periods of time is critical to the development of certain skills. For example, the young male chaffinch deafened early in life subsequently develops an abnormal song (Nottebohm, 1970). Similarly, a white-crowned sparrow raised in social isolation from the 5th day of life develops an abnormal song (Marler, 1970). Experiments with kittens have shown that altered visual stimulation (e.g., exposure to only striped patterns) may modify the response characteristic of neurons of the visual cortex with behavioral consequences (Lou, 1982).

There are examples from humans as well. Hearing oneself and others is important in the development of human speech, as evidenced by the difficulty with which the congenitally deaf learn to speak (Lenneberg, 1969). Clearly, the timing of exposure to a given stimulus appears to be as important in the development of human responsiveness as it is with animals. As mentioned previously, amblyopia will result if a squinting eye is not corrected early in life (Lou, 1982). Similarly, a person having

a cataract removed late in childhood, as opposed to early childhood, will never see as well (Lou, 1982). Further, one eye may lose function almost completely if binocular vision is hampered early in life, e.g., strabismus or severe monolateral refraction anomalies. Apparently this loss is due to a permanent change in the neurons of the primary visual cortex. The effects of monocular deprivation can be reversed during the first years of life if proper stimulation of the formerly deprived eye is assured (Lou, 1982). Lou concluded that there is considerable evidence that stimulation and experience change the physiologic, biochemical, and morphologic characteristics of the nervous system. Therefore, we might speculate that the preterm infant who is subjected to an environment which is not the one of normal development is at risk for interferences in the normal development of sensory responsiveness.

In particular, there has been considerable concern about noise levels in the intensive care nursery. Noise levels in the nursery are clearly above those found in the home environment. It is known that even mild exposure to intense sounds can produce a temporary threshold shift from which one recovers following removal from the sound. However, prolonged exposure to intense sound can produce a permanent threshold shift in which hearing loss persists throughout life (Saunders & Bock, 1978). Apparently, intense noise causes a dramatic loss in normal hair cell function and a general failure of the primary neurons to discharge in synchrony. The outer cells of the cochlea are more easily damaged than

the inner hair cells; following exposure to extreme noise conditions there is severe hair cell degeneration and extensive structural damage to the organ of Corti (Saunders & Bock, 1978). Recently it was found that noise such as the phone ringing or isolette door closing can also produce hypoxemia in preterm infants (Long, 1982).

One study of intensive care nursery noise found that sound levels averaged between 70 to 80 dB; the overall noise environment was comparable to that of light auto traffic and at times reached that of the noise produced by large machinery. Interestingly, light and sound recordings in the incubator were virtually identical to those in the intensive care unit, contradicting the commonly held belief that the plastic walls of the incubator shield the child from noise (Blennow, Svenningsen, & Almiquist, 1974). Bess, Peek, and Chapman (1979) demonstrated that merely closing the metal doors of the incubator generated impulse sounds over 100 dB. Of particular concern is the multitude of sound sources in the form of various monitor alarms, human beings interacting, and other equipment noises. It has been estimated that the infant is exposed to a mean of 60 dB for anywhere from 1 to 90 days of life in contrast to the 40 dB experienced in the average home bedroom (Kellman, 1982).

In spite of the concern about noise, there has been little evidence demonstrating a connection between noise in the neonatal intensive care unit and later hearing impairment in preterm infants. However, there is evidence that preterm infants do experience hearing loss. A study which

attempted to ascertain the etiology of hearing loss in 290 cases of partially and profoundly deaf children found that approximately 44% of the cases appeared to be due to rubella; anoxia; prematurity; or meningitis, encephalitis, or mumps occurring prenatally, perinatally, or during childhood (Morgan, Charachon, & Bringuier, 1970). Some investigators feel that the sensorineural or conductive hearing loss in the preterm neonatal intensive care unit population seems to be correlated with medical complications, early gestation, or perinatal hypoxia rather than length of stay or use of respirator or incubators (Northern & Down, 1978; Simmons, 1980). Of course, those infants with early birth and perinatal hypoxia typically have the longest hospitalization, making it difficult to determine the etiology of hearing loss. Some findings suggest the possibility of detrimental effects of environmental noise: 12 low-birthweight infants who had been in incubators for at least 1 week and who were without history of birth trauma or other illness had severe high tone loss typical of traumatic deafness (Douek, Bannister, Dodson, Ashcroft, & Humphries, 1976).

Incubators, in particular, have been considered a potential source of damaging noise. The noise level of modern incubators is less than 55 dB for frequencies over 1000 Hz, which is less than the 90 dB considered to be unsafe in industrial conditions. Their safety, however, is not clear since the 90 dB used as a safe value is based on adult safety levels (Kellman, 1982). Obviously, there is some disagreement as to what might be safe noise levels for preterm infants.

A major consideration in the argument concerning whether noise levels in incubators cause hearing loss is the immaturity of the organism (Douek et al., 1976; Kellman, 1982; Saunders & Bock, 1978). Adult guinea pigs exposed to incubators suffered no damage to sensory cells, however; guinea pigs in their 2nd week of life suffered destruction of a proportion of sensory outer hair cells in the cochlea, suggesting a critical period when the cochlea is sensitive to noise damage (Douek et al., 1976). This finding supports the earlier presented notion of critical periods of development. Saunders and Bock (1978) claimed that shortly after the onset of normal auditory function there is a critical period of time during which the inner ear is overly susceptible to acoustic trauma. Results from hamster, mouse, and guinea pig experiments suggest that the critical period begins shortly after the auditory system begins to function normally. There appears to be no answer to the question of whether the human infant passes through a period of heightened sensitivity to acoustic trauma. However, if the critical period follows the onset of auditory function, the human fetus could be especially susceptible 12 to 16 weeks before birth (Saunders & Bock, 1978). It would seem that infants born 12 to 14 weeks prior to usual birth and even earlier may be at risk for hearing loss. Even if there is no hearing loss, one can still question whether continuous noise that is not contingent upon the infant's activities can affect auditory behavior.

Infants cared for in intensive care generally are exposed to bright

fluorescent lights for 24 hours a day. It is not clear what the effect of this exposure might be since there are no studies that have attempted to sort out the effects of continual lighting on preterm infants. However, it is thought that circadian rhythms are induced by alternations of light and darkness (Minors & Waterhouse, 1982). It is also known that maternal biorhythms seem to affect fetal activity, with fetal activity increasing during the day and being greater during the evening than morning (Minors & Waterhouse, 1982). It may be that lighting of the nursery contributes to the absence of circadian rhythm in the preterm infant. One might also speculate that continuous bright lighting alters visual attentiveness.

Alterations in Parenting

Premature infants are also separated from their parents. There has been considerable attention directed toward the effects of separation on the development of a parent-to-child bond. A number of clinicians have observed that parents appear to go through a grieving process following the birth of a preterm infant (Barnett, Leiderman, Grobstein, & Klaus, 1970; Benfield, Leib, & Renter, 1976; Caplan, 1970; Choi, 1973; Kaplan & Mason, 1960; Klaus & Kennell, 1976). Early termination of the pregnancy is felt to interfere with the normal psychological processes of pregnancy (Bibring, Dwyer, Huntington, & Valenstein, 1961). In addition, there is usually little celebration in the birth of a preterm infant in contrast to that of a fullterm infant. Gorski (1983b) pointed out that parents of premature infants "endure months with no baby at home yet no baby in

the womb either, creating a unique pregnant/nonpregnant state of suspended emotional direction" (p. 9). This grief reaction, seemingly resulting from the loss of the normal fullterm infant and from the threat of permanent loss of the preterm infant, may interfere with the parents' ability to interact with their newborn infant.

Further, the development of maternal bonding to the child has been linked to the opportunity for contact with the infant, such as touching and caregiving during the early postnatal period (Kennell, Jerauld, & Wolfe, 1974; Klaus & Kennell, 1976; Minde, Trehub, Corter, Boukydis, Celhoffer, & Marton, 1978; Rubin, 1963). Such opportunities are often missing or at least infrequent for the parents of the premature infant. While the infant is in the nursery, the parents are often able to contribute little to the infant's care, causing frustration and anger.

As for direct effects of separation on the infant, animal work may serve to help us examine the potential effect of separation from parents. Animal work suggests that in many species, including rats, cats, dogs, and monkeys, the sensory stimulation provided by physical contact between the young animal and the mother, or some other adult animal, is needed for normal somatic growth and behavioral development (Schanberg & Kuhn, 1979). In monkeys, for example, a high percentage of time is spent in close contact with the mother during the first month of life (Harlow, Harlow, & Hense, 1963; Hinde, 1974; Horwich & Weirman, 1978). Monkeys restrained from physical contact showed abnormal

behavioral development even when visual, auditory, and olfactory interaction was maintained (Harlow & Harlow, 1965; Harlow & Zimmerman, 1959; Hinde & Spencer-Booth, 1971). Further, kittens deprived of contact from the 2nd week of life learned more slowly as adults, and puppies deprived of tactile stimulation showed profound disturbances in behavioral development (Casler, 1961). Schanberg and Kuhn (1979) demonstrated that rat maternal deprivation was associated with a marked decrease in both serum growth hormone as well as loss of sensitivity in various tissues to growth hormone itself.

Human children receiving adequate nutrition and medical care but inadequate maternal attention failed to grow normally, sometimes were mentally retarded, and demonstrated abnormal behavior (Barbero & Shaheen, 1967; Casler, 1961; Silver & Finkelstein, 1967). Whether or not the premature infant's separation from parents causes a decrease in growth hormone or other adverse effects is not known; however, it seems quite possible that the noted decreased responsivity of premature infants and difficulties with obtaining adequate growth may be related to early separation as well as the more obvious physiological immaturities.

Another source of interference with normal parent-child interaction is the infant. Emphasis in the intensive care nursery is often on the infant's physiological parameters rather than behavioral responses, thus the staff often unwittingly retards the parents' progress toward viewing their child as an individual with unique responsiveness (Gorski, 1983a).

Blackburn (1983) feels that the premature infant often emits unclear or inconsistent behavioral cues and frequently responds quite differently from the more mature infant. Further, she feels that if the infant's signals differ from the parents' expectation or if the parents cannot read the cues, the parents may become frustrated, confused, and discouraged. The premature infant often appears unresponsive, provides few opportunities for eye-to-eye contact, and has exaggerated behavioral responsiveness, such as startles, jerky movements, and tremors, which are disconcerting to parents, who may feel they are frightening or hurting the infant. Gorski (1983a) stated that the behaviorally immature preterm infant tends to be a weak social interacter with limited abilities to elicit, pace, or follow a dyadic interaction.

The long-term outcome of these hindrances to the early parent-child relationship is not clear. Gorski (1983a) spoke of the psychological morbidities which are "functionally crippling" beyond any real physical impairment. He speculated that the fears parents retain from the initial life threat can pervade and influence a host of subsequent relationships to the child. Some investigators have speculated that the mothers are less confident in their caretaking (Seashore, Leifer, Barnett, & Leiderman, 1973). Others (e.g., Field et al., 1978) have noted differences in the ways in which mothers and preterm infants later interact: The infants show more gaze aversion than fullterm infants, and the mothers seemingly overstimulate their premature infants. Divitto (1979) noted that the sicker the

infant, the more likely she/he was to be held at arms' length on the lap and the less likely she/he was to be nestled close in the arms, touched, and talked to. Others have speculated that anxiety and the need for support by mothers of preterm infants are factors contributing to maternal overstimulation seen as a form of overcompensation or inability to respond to the infant itself (Blake, Stewart, & Turcan, 1975; Minde et al., 1978).

For the purposes of this research, concern lies with the more immediate effects of illness on the infant's responsiveness. Minde (1982) found that sick infants moved less and opened their eyes less during interaction with their mothers than did infants with fewer complications, and the mothers of sick infants interacted less with their sick infants. Nurses, too, have been found to infrequently interact socially with these infants (Korones, 1976). It was found in a recent detailed analysis of nurses' caretaking activities that little time was spent with the baby before or after a specific task was carried out (Gorski & High, 1983). Therefore, it is unlikely that the mother surrogate, the nurse, substitutes for the more typical mother-child interaction.

Summary

While it is difficult to demonstrate a cause and effect relationship between particular environmental factors and the sensory responsiveness of the preterm infant, it is clear that there are multiple environmental factors which have been shown to cause specific alterations in the

developing organism's behavior both in animal and human studies. Physiological parameters, such as EEG patterns, sleep cycles, visual evoked response, and auditory responsiveness, have been shown to be altered in preterm infants, particularly those suffering prolonged medical illness. An example is the finding that infants with hyaline membrane disease appear to have altered sleep cycles (Karch et al., 1982). While this is not direct evidence for altered responsiveness, state certainly is known to affect responsiveness; therefore, alteration in state secondary to the combination of prematurity and respiratory distress syndrome suggests that these infants would be less responsive to sensory stimulation. Drugs may actually affect the brain morphology or affect nervous system function, thereby potentially affecting the infant's ability to respond. Nutrition, too, may actually alter the brain's morphology. Further, poor nutrition has led to poorer performance on developmental exams. Considered in this light, one could speculate that inadequate nutrition might decrease the infant's ability to respond or alter the infant's ability to regulate incoming stimuli. The effects of multiple aversive procedures are unclear but certainly these experiences may cause the infant to withdraw and be less available for sensory input. Altered noise and light levels appear to at least potentially put the infant's ability to respond to sensory stimuli at considerable disadvantage, and they may cause actual damage, as suggested by animal studies. Separation from parents, particularly without a clear mother surrogate, may alter the infant's ability to respond.

Certainly, this effect has been demonstrated in animal models. In animal models, separation with its subsequent lack of tactile stimulation has been shown to cause decreased growth hormone with subsequent weight loss. Further, without a consistent mother to interpret and modulate caretaker-infant interaction the infant may not learn to respond in the same way as the fullterm infant, thereby altering his sensory responsiveness. It seems clear that there are ample reasons to be concerned about the preterm infant's responsiveness to sensory stimuli of a social nature.

Conclusions

The conclusions to be drawn from this review of literature on the sensory responsiveness of preterm infants set the stage for several features of the present study: (a) its focus on describing how the very immature human infant responds to sensory stimuli; (b) its focus on tracing developmental changes in sensory responsiveness prior to term; (c) its use of animate tactile and auditory stimuli such as those usually provided by caregivers; and (d) its emphasis on analyzing sensory responsiveness and its development separately for subgroups of premature infants thought to differ meaningfully in biological status and early environmental experiences.

First, this review of existing literature documents that we know very little about the sensory responsiveness of the very immature infant. With the possible exception of visual processing, there are few studies which look at the response of the very immature infant to a specific type of

sensory stimulation. Responsiveness to proprioceptive stimuli has been studied only in fullterm infants. Responsiveness to vestibular-proprioceptive stimulation has been described mostly in terms of later differences in outcome for preterm infants rather than in terms of behavioral responsiveness at the time of application of the stimulation. Similarly, responsiveness to tactile stimulation has not been evaluated until 37 weeks' postconceptional age.

Second, the early developmental course of sensory responsiveness is unclear. Visual responsiveness has been assessed as early as 28 weeks' postconceptional age with the finding that infants of 30 weeks fixate on patterned stimuli and at 35 weeks discriminate between visual stimuli. Visual responsiveness to social stimuli (e. g., the caretaker's face) has not been charted. Behavioral responsiveness to tactile and vestibular-proprioceptive stimuli has not been traced from preterm birth to normal time of birth. Further, when evaluated at 37 weeks it was in terms of response to an artificial stimulus, a plastic filament, not in terms of stroking and touch as described in intervention studies. The developmental course of auditory responsiveness was traced from 29 weeks' gestation, but only in terms of a response to pure tones and clicks, not in terms of a recorded voice as described in intervention studies. There appears to be a need for more descriptive information regarding the development of sensory responsiveness.

Third, there is little information on how sick preterm infants

respond to sensory stimulation as compared to relatively well infants. Unfortunately, preterm infants have often been treated as a homogeneous group without consideration of the potential differences in infants born at 33 weeks versus those born at 28 weeks, or infants with major medical complications versus those with few complications. There seems to be ample evidence that illness could affect sensory responsiveness. Therefore, it seems important to differentiate among preterm infants in our attempts to understand their sensory responsiveness.

Despite our lack of knowledge about the development of responsiveness to social stimuli by preterm infants, important clinical reasons exist for such knowledge. One set of reasons concerns the caregiver. Preterm infants are often seen as relatively unresponsive and unrewarding to care for and even as frustrating to the caretaker. Mother surrogates, the nursing staff, often have difficulty seeing the immature infant attached to various life support systems as a baby with potential for interaction. Demonstrations of responsiveness to sensory input, especially human sensory input, could be important for the caregiver. Perceiving such responsiveness might enable the nurse to feel that the infant is responding to her caretaking, thereby increasing the sense of the worthwhileness of what is often frustrating work. Additional information about responsiveness might lead to the nurses' providing the infant with appropriate sensory stimulation. In the intensive care nursery there is often a striking lack of touching and talking other than that required for caretaking

(Gorski & High, 1983; Gottfried et al., 1981; Korones, 1976). Similar concerns obviously exist for the parents, who not only have concerns in the early weeks following birth but will be interacting with the child for years to come. As noted earlier, parents have limited contact with their infant and may have difficulty seeing their child as an individual capable of responsiveness to their input. Further, they often do not know how to interpret the infant's cues (Gorski, 1983a). The very sick infant offers a particular challenge to interaction (Minde, 1982).

Given the potential problems of parenting, it seems that increasing the parents' sense of the infant as an active participant in the interaction could have positive effects. As mentioned earlier, Minde (1982) found that maternal behaviors of talking, holding, feeding, and touching depended primarily on the size and medical status of the infant. However, they also found that the mother's touch influenced eye opening in the relatively more mature infants. Johnson (1983) suggested that a source of stress to parents is the fact that the baby does not respond as they anticipated and that this mismatch may be interpreted as dislike or disapproval. She suggested that such a conclusion may have a negative impact on parenting and consequently on the child's behavior and emotional state. Therefore, she recommended encouraging eye-to-eye contact and touching and stroking to help allay parents' fears about the infants' behaviors and their own performance. It would seem that if responsiveness could be demonstrated to the parent, more participation might occur during visits to the ICN,

potentially enhancing the parent-child interaction. Success in eliciting an infant's response might increase maternal self-confidence. A recent study demonstrated to the mother her preterm infant's capabilities on a modified Brazelton exam and found that those mothers called and visited more than mothers not receiving demonstrations, providing the mothers were sufficiently close to visit or had travel funds. These infants, in turn, also showed more looking and vocalizing and less motor activity during interaction with their mothers (Eyler, 1980).

A further set of reasons to gain information regarding sensory responsiveness concerns our efforts to provide a sensory environment for the preterm infant conducive to normative development. With the current dearth of knowledge regarding the development of sensory responsiveness, it is not possible to recommend a particular program of infant stimulation. Only with understanding of how the preterm infant responds to a variety of sensory stimuli can intervention efforts directed toward facilitating and enhancing sensory responsiveness be undertaken in an informed manner. While one study certainly does not provide all the answers needed, it is a step toward developing a conceptual framework for providing the infant with age-appropriate sensory stimulation.

Thus, the present study traced the development of responsiveness to social stimuli of talking and touching in preterm infants born at 30 or less weeks' postconceptional age. As soon as the infant was medically stable (no later than the 2nd week of life), responsiveness to talking and

touching was assessed three times a week until discharge or transfer, at least 34 weeks' postconceptional age for all infants in the study. Sensory responsiveness was assessed through changes in body movement, eye movement, facial and mouth activities, and heart rate, and it was expected that infants would show changes in these activities with stimulation. It was predicted that talking would be associated with less body movement and more eye movement because these responses, suggestive of an orienting response, have been noted in fullterm infants. Further, it was predicted that touching and the combination of talking and touching would be associated with more body movement since touching has been associated with increased body movement in fullterm infants, and it was not expected that combining talking with touching would lessen this response. Repeated assessments at different ages allowed testing of the hypothesis that infants would respond differently with increasing age; it was expected that eye movement and body movement would increase as the infants approached the time of usual birth. Infants of varying degrees of illness were studied to explore the hypothesis that sick infants would respond differently than less sick or well infants because of the possible alteration in their central nervous system development. More specifically, it was felt that sick infants would attend and alert less often to weaker stimulation (talking only) than well infants. Further, it was predicted that sick infants would respond with more body movement to touching, suggesting a defensive response because of their multiple experiences with aversive procedures.

CHAPTER II

METHODS

Subjects

Premature infants of 26 to 30 weeks' postconceptional age admitted to Duke Hospital's Intensive Care Nursery between January 1 and May 1, 1983, were the subjects of the study. Infants were recruited if they fulfilled four criteria: (a) 30 or less weeks' gestational age at birth; (b) normocephalic at birth, defined as a head circumference between the 10th and 90th percentiles on the Colorado growth curve (Lubchenco, Hansman, Dressler, & Boyd, 1963); (c) appropriately grown at birth, defined as weight between the 10th and 90th percentiles on the Colorado growth curve; and (d) without major congenital defect. Gestational age was determined from the date of the mother's last menstrual period and substantiated through physical examination of the children during the 48 hours after birth using the Dubowitz exam to determine maturity (Dubowitz, Dubowitz, & Goldberg, 1978). Where there was less than 2 weeks' difference between the mothers' dates and the Dubowitz exam, the mothers' dates were used. Fifteen infants formed the study group. They ranged from 720 grams to 1450 grams in birthweight and had a mean gestational age of 28 weeks. Six infants were the products of twin

gestations. In all, there were 7 females and 8 males: 6 black females and 5 black males, 1 American Indian male and 1 Caucasian male, and 1 male and 1 female Indian infant. Seven of the infants were firstborn. Maternal age ranged from 19 to 37 years (mean = 25). Informed parental consent was obtained from all parents (Appendix A). (See Table 1 for a description of individual subjects.)

Other infants (n = 15) who met the study criteria during the encatchment period were not included in the study because of their extremely unstable condition which resulted in death in the 1st week of life (n = 10), parental refusal (n = 1), or constraints of the study procedure which limited the number of infants who could be studied at one time (n = 4).

Two ways of assessing the degree of illness of each subject were utilized. A sickness index scale developed by Minde, Whitelaw, Brown, and Fitzhardinge (1983) was used to assess the degree of illness each infant suffered. This illness index includes the major neonatal problems such as respiratory distress, sepsis, neurological problems, adequacy of feeding, and metabolic problems (Appendix B). The sickness index counts the occurrence of major complications of prematurity on a daily basis, and the total sickness index is the total score obtained from daily assessments during the infant's hospitalization. For the purposes of this study, the total sickness score reflected the score obtained by 38 post-conceptional weeks of age.

In addition, head growth during the ICN stay was assessed as a

Table 1

Description of the Study Population

Subject	Gestational age at birth (weeks)	Birth weight (grams)	Twin birth	Race	Sex	First-born	Total sickness index	Change in head circumference	Weeks of observations
Well group									
1	30	1350	No	Black	Male	No	11	3.25+	30-34
2	30	1420	Yes	West Indian	Male	Yes	44	3.00	30-34
3	29	1100	Yes	Black	Male	Yes	52	4.50	30-34
4	28	1005	Yes	Black	Male	No	58	5.00	28-34
5	29	1220	No	Black	Female	No	21	4.25	29-34
Moderately sick group									
1	29	1170	No	Black	Female	No	107	3.75	29-37
2	28	910	No	White	Male	No	156	3.00	29-37
3	28	1098	Yes	Black	Male	No	216	4.00	29-37
4	28	950	No	American Indian	Male	Yes	134	3.00	28-34

Sick group

1	26	720	No	Black	Female	No	284	1.25	26-37
2	30	1450	Yes	West Indian	Female	Yes	114	2.20	31-37
3	26	890	No	Black	Female	Yes	176	0.50	27-35
4	27	1000	No	Black	Female	No	280	2.75	28-37
5	29	1150	Yes	Black	Male	Yes	269	1.00	30-37

summary measure of the impact of medical complications on brain growth. A previous study had determined that head growth during the first 6 postnatal weeks summarized the deleterious effects of multiple medical complications and was strongly related to the quality of developmental outcome at both 15 and 24 months of age (Gross & Eckerman, 1983; Gross, Oehler, & Eckerman, 1983). In the present study, the median change in head circumference during the first 6 weeks of life, 2.9 cm, was used to distinguish infants who were unlikely to be compromised in brain growth ($\geq$ 2.9 cm) from infants suspected to be compromised in brain growth (< 2.9 cm).

Using these two assessments of severity of illness, the present study group was subdivided into three groups. Five infants with a sickness index of less than 60 and head growth of at least 2.9 cm in the first 6 weeks composed the well group. Another five infants were clearly very ill, with a sickness index greater than 150 and head growth less than 2.9 cm in 6 weeks, and composed the sick group. The remaining four infants were called moderately ill; they had a sickness index greater than 60 but with head growth 2.9 cm or greater. One subject who failed to fit in any of these categories was dropped from the analyses.

Procedure

In thinking about the sensory stimuli to study, three issues were central. A major concern was identifying sensory stimulation that could be easily applied without interfering with the equipment or medical

treatment of a very immature infant. A second issue was that the stimuli should be able to be meaningfully applied when the state of the infant (e.g., asleep, drowsy, alert, etc.) was indeterminate or varying. A third concern was to identify sensory stimuli that would appear natural to a caretaker or parent and could be expected to occur as a routine part of caregiving.

Two such types of stimulation were decided upon--talking and touching in the form of stroking. Parents are told to stroke their preterm infant and to talk to the infant, and we assume these activities are part of the caregiver's natural repertoire. Stroking the infant and talking to the infant also are safe stimuli for the immature infant. They can be applied and responsiveness assessed over the entire course of the infant's hospitalization. In addition, as described above, there are data which suggest that the immature organism is capable of responding to tactile and auditory stimulation. It was also decided that both stimuli would be applied together as well as independently to assess the effects of combined sensory stimulation. Persons frequently spontaneously touch and talk to the infant; however, it is not clear that this combined stimulation is appropriate for the very immature infant, who conceivably may be taxed by more than one stimulus.

Thus, episodes of talking, touching, and the combination of talking and touching were used in assessing sensory responsiveness. Each assessment began with an 80-second period where no planned stimulation

was presented (pre-stimulus condition). There followed three 80-second periods of stimulation alternating with 80-second undisturbed periods. The order of presentation of the three forms of stimulation was counterbalanced across sessions and infants.

Data collection for the 15 subjects began when they were regarded as medically stable. For 8 subjects, this was the 1st week of life, and for 7 it was the 2nd week. Each subject then had three assessments per week of behavioral responsiveness to talking and touching until the subject reached 38 weeks' postconceptional age or until transfer from the unit. Three assessments per week were obtained for the 14 subjects used in data analyses during weeks 30 to 34 postconceptional age. Individual infants had assessments beginning as early as 27 weeks and continuing as late as 37 weeks. Table 1 lists the subjects by illness group and gives the week of the first and last observation, the total sickness index, and the head circumference change from birth to 6 weeks.

Talking was provided by an adult female talking in a low, soft, "soothing" voice about anything that came to mind. For infants in an open bed, the examiner leaned forward and spoke directly to the infant. For infants in incubators, the adult spoke directly through an open porthole near the infant's head. Talking was chosen as a means of auditory stimulation because the infant is constantly exposed to speech and because talking is something which a caregiver can easily do. Further, there is evidence that, at least in fullterm infants, an orienting, eye-opening, eye-

shifting, head-turning response can be induced by speaking to the infant in a soft voice (Brazelton, 1973). Live, spontaneous conversation, even though less uniform across presentations, was chosen over a taped voice because it was felt a spontaneous attempt to interact with the infant was more like that naturally occurring between mother and child and more likely to evoke a response. In addition, repeated use of exactly the same message might induce habituation.

Touching was provided by the same adult female stroking various parts of the infant's body. Such stroking seems part of the mother's natural response to a very young infant (Rubin, 1963). Further, the intervention studies using stroking and massaging have shown positive effects, as noted in the Introduction of this paper. Since it is unclear that stroking of any particular body area offers advantage over any other, all areas were stroked using a technique similar to that described by other investigators (Solkoff et al., 1969; White & Labarba, 1976). The adult female successively stroked with one hand the infant's legs, arms, chest or back (depending on whether the infant was prone or supine), and head for 10 seconds, repeating the sequence for a total of 80 seconds. The adult was cued to move from one body part to another by the coder's pencil moving from one 10-second block as the coding proceeded. This cue ensured that the adult stimulators were as uniform as possible in their stroking of the infant.

During the combined talking and touching condition the same adult

female talked to the infant while stroking the infant in the previously described manners.

Ten adult females were used to provide the stimulation. Each was a nurse experienced in the care of very immature preterm infants. They talked with and observed the investigator, as well as each other, in an attempt to make the stimulation as uniform as possible. The same adult provided all the stimulation during any one assessment.

The assessment of responsiveness was done at nonstandardized times determined by the accessibility of the nursing staff and the routines of infant care. Each subject had only one responsiveness assessment in a given day. All data were collected during the daytime between 8 a.m. and 6 p.m., 7 days a week. The assessments were done halfway between feedings whenever possible since this is suggested as an optimal time for engaging the infant in social stimulation (Brazelton, 1973). Further, the assessments were not done immediately after a painful procedure.

Response Measures

Coding

Three sets of infant behaviors were assessed at 10-second intervals: body movement, eye movement, and a miscellaneous category that included smiles, hand-to-mouth activities, yawns, tongue protrusion, grimaces, and cries. In order to code all these types of activity, the coding was done at 10-second intervals signaled by a click delivered to the coder's ear via an earpiece. Prior schemes for coding

responsiveness to tactile and auditory stimulation in preterm infants were reviewed (Field et al., 1979; Minde et al., 1983; Schmidt et al., 1980). All counted the number of extremities moving, and Field et al. also gave a plus for vigorous movement and a minus for minimal movement. In addition, Minde et al. coded separately arms, legs, and head movement; eyes open and closed; eyes scanning; smiles; mouth movement; crying; vocalizing; yawns; grimaces; and hand-to-mouth movements. The final coding scheme closely resembled that of Minde et al. (1983).

The coding of body movement assessed the amount of gross body movement exhibited by the infant. Changes in the level of gross body movement can be counted as reflecting responsiveness to stimulation; such body movements are also used in assessment of the infant's state before stimulation. The number of body parts moving during a 10-second period was counted, resulting in a score ranging from 0 to 5 for each 10-second period. For example, an infant moving all four limbs and the head received a score of 5. These scores were summed across the eight 10-second periods composing a specified stimulus condition, and this sum was used for data analyses.

The coding of eye movements assessed the amount of eye opening and eye movement during a 10-second interval. Certainly, it has been the experience of this investigator that parents of the preterm infant appear to place a high premium on eye-opening behavior. Visual regard has been seen as an enhancer of the attachment process (Klaus & Kennell, 1976).

Open eyes and shifting of eyes have been seen as signaling an alert state (Brazelton, 1973). Each 10-second period received a score of 0 (eyes closed throughout), 1 (eyes open for some portion of the period), or 2 (eyes moving in any direction during part of the period). Again, the sum of these scores over the eight 10-second periods composing a stimulus condition was used in the analyses.

The category of miscellaneous behaviors included: yawn, grimace, tongue protrusion, cry, smile, and hand-to-mouth activity. Four of these behaviors (yawns, grimaces, tongue protrusion, and cries) have been described as ways infants signal their wish to terminate the stimulation (Als & Brazelton, 1981) and thus are viewed in the present study as possible "avoidance" signals. The two remaining behaviors (smiles and hand-to-mouth activity) have been thought of quite differently. The meaning of smiling in infants less than 44 weeks' postconceptional age is unclear but has been noted to increase with mild stimulation (Wolff, 1966). Regardless of the reason for smiling, the caregiver is likely to interpret it as a positive response. Hand-to-mouth activity has been seen as a way the infant has of stabilizing himself when reacting to stimuli from the environment (Als & Brazelton, 1981). Since these activities do not appear to be avoiding activities, they were considered as possible "processing" signals. Therefore, for this miscellaneous category, two scores were compiled. One score was the total number of 10-sec intervals during a stimulus condition in which smiles and/or hand-to-mouth activities

occurred; a second score was the total number of 10-sec intervals during a stimulus condition in which any "avoidance" signals occurred. Hence, each score could range from 0 to 8.

A fourth dependent measure was heart rate. Heart rate was recorded for infants who were attached to cardiac monitors. No attempt was made to measure heart rate for infants without monitors since applying leads might disturb the infant and therefore interfere with the assessment of responsiveness to specific stimuli. Furthermore, there is a hospital charge for the use of monitors which could not be justified by infant need. The audible output of the cardiac monitors was recorded on audiotape. Subsequently, a coder listened to the tape and, using a microprocessor-based data-acquisition system, recorded the time of occurrence of each heartbeat for the 10 seconds preceding the beginning of a new stimulus condition and the first 10 seconds of that stimulus condition. (The tape was verbally cued at 10 seconds before the onset of stimulation and at the beginning of the stimulation.) The interval of 10 seconds was used because the literature suggests that heart rate changes are only seen shortly after the presentation of a given stimulus (Adkinson & Berg, 1976; Berg, 1974). The computer then calculated the mean number of seconds between beats for the 10-second pre-stimulus interval and the first 10 seconds of stimulation; these means were used in the data analyses since they reflect the mean heart rate (60 divided by the time between beats).

Intercoder Agreement

Reliability checking of the live coding was done at least once a week for a total of 27% of all assessments. The reliability assessments were evenly distributed across infants. Reliability, using a Pearson Rank Order correlation, on scores for each 10-second interval of an infant's assessment, ranged from 0.6 to 1 for body movement (mean = .97 $\pm$ 0.05) and 0.65 to 1 for eye movement (mean = .97 $\pm$ 0.07). Agreement for facial expression was assessed by comparing the total amount of movement per assessment recorded by each coder. The totals disagreed by more than 2 only on 5 of the 90 co-coded sessions.

A coder who had no other relationship to the study punched in the heartbeat data for the first 30 tapes. The investigator randomly selected 20 of these sessions for reliability checks. Pearson Rank Order correlations were done on both prestimulation intervals and stimulation intervals with .92 and .81 correlations, respectively. A second method for checking reliability was also used. For the same 20 sessions, the percentage of agreement for heart rate increase, decrease, or no change was noted. (The criterion for change in either direction was five beats per minute.) Agreement regarding heart rate increases, decreases, or no change was 77%. The remaining tapes (21) were done by the principal investigator and checked at random for intraobserver reliability. Pearson Rank Order correlations were .89 and .93 for the prestimulation and stimulation assessments, respectively. There were two disagreements in 15 checks for increases or decreases or no change.

Other Measures

In addition to the responsiveness assessments described, there were weekly assessments of neurological reflexes and orientation items from the Brazelton Neonatal Behavioral Assessment Scale, as the infant's condition permitted. During each weekly assessment, a number of elicited reflexes (sucking, Moro, palmar grasp, rooting, placing, tone and posture, ventral suspension, head control and posture when sitting, traction response, and response to passive movement) were given a graded response depending on the completeness of the response. Other reflexes (incurvation, glabella, clonus, Babinski, crawling, nystagmus, tonic deviation of eyes, automatic walking) were simply coded as present or absent. The ranked responses were derived from rankings of neurological assessments by other clinicians (Amiel-Tison, 1976; Campbell & Wilson, 1976). Appendix C gives the assessment form used and the scale for ranking of the selected reflexes. During the Brazelton exam, responsiveness to animate visual and auditory stimuli (human face and voice) and inanimate visual and auditory stimuli (red ball and bell) were assessed. The Brazelton scoring system was used for these items (Appendix D).

CHAPTER III

RESULTS

Analyses of the Effect of Stimulus, Postconceptional Age, and Illness Groups

The major statistical analyses of the effects of the different stimulus conditions, different postconceptional ages, and illness groups were conducted on the data collected during weeks 30 to 34 postconceptional age since three assessments per week were completed for each subject during these weeks. The original plan for statistical analysis was a four-factor repeated measures analysis of variance (Age x Illness x Talk x Touch). However, there was not enough independent information in the data matrix to solve a four-way analysis. Instead, two separate two-factor repeated measures analyses of variance were performed.

To assess the effects of illness and stimulus conditions, 3 x 2 (Illness x Stimulation) repeated measures analyses of variance compared behavior during the pre-stimulus condition to that with a specific stimulus condition (pre-stimulus or stimulus condition; within subjects) for each illness group (3 levels of illness; between subjects). Separate comparisons were done for each dependent measure. There were 15

separate repeated 3 x 2 analyses of variance: (Illness x Talk) for each of the 5 dependent measures; (Illness x Touch) for each of the 5 dependent measures; and (Illness x Talk & Touch) for each of the 5 dependent measures. Table 2 presents the means for each dependent measure for each stimulus condition.

To assess the effects of illness and postconceptional age, 3 x 5 (Illness x Age) repeated measures analyses of variance compared the behavior for each illness group (3 levels of illness; between subjects) across postconceptional ages 30 to 34 weeks (5 levels of age; within subjects). There were a total of 20 separate such repeated measures of 3 x 5 analyses: one for each of the 5 dependent measures for each of the stimulus conditions (pre-stimulus, talk, touch, and the combination of talk and touch). Tables 3-7 give the means for each dependent measure in the Illness x Age analysis.

A significance level of $\underline{p} < .05$ was used for the main and interactive effects in both sets of analyses. In the age and illness analyses, univariate trend analyses were done for age and for the interaction of illness with age; and because of the multiple comparisons, a significance level of $\underline{p} < .01$ was used in an attempt to avoid Type I errors.

Stimulus Effects

Means for each dependent measure (body movement, eye movement, heart rate, smiles and hand-to-mouth activity, and "avoidance"

Table 2

Mean Scores for Dependent Measures for Each Illness Group During Stimulus Conditions

Illness group	Pre-stimulus	Talk	Touch	Talk and touch
		Body movement		
1	7.9	6.4	15.1	13.9
2	5.5	4.5	14.0	14.1
3	7.8	5.9	16.0	17.6
		Eye movement		
1	0.9	1.9	1.3	1.1
2	1.2	2.1	1.3	0.9
3	1.3	2.3	1.7	1.5
		Heart rate		
1	.417	.412	.411	.416
2	.418	.420	.415	.419
3	.416	.420	.408	.416
		Smiles and hand-to-mouth activity		
1	.64	.65	.69	.67
2	.08	.16	.28	.35
3	.18	.23	.26	.21
		"Avoidance" signals		
1	.39	.13	.47	.60
2	.53	.28	.48	.45
3	.52	.47	.57	1.11

Table 3

Mean Amount of Body Movement for Each Illness Group at Postconceptional Ages 30 to 34 Weeks During Stimulus Conditions

	Stimulus condition											
	Pre-stimulus			Talk			Touch			Talk and touch		
Age	Illness group			Illness group			Illness group			Illness group		
	1	2	3	1	2	3	1	2	3	1	2	3
30	3.5	3.9	7.0	5.4	3.2	3.8	11.1	12.5	18.8	14.0	8.8	19.2
31	10.7	4.3	7.6	6.0	8.3	9.5	14.9	11.3	15.7	11.3	14.5	16.2
32	9.1	3.0	7.2	4.6	4.3	4.1	15.3	14.4	15.1	12.9	14.3	17.7
33	7.0	7.8	7.5	8.5	3.9	7.5	20.1	17.1	15.9	16.7	16.8	18.5
34	9.2	8.7	7.7	7.3	2.8	4.4	14.3	14.6	14.1	14.6	15.2	16.9

Note. Illness groups: 1 = well, 2 = moderately sick, 3 = sick.

Table 4

Mean Amount of Eye Movement for Each Illness Group at Postconceptional Ages 30 to 34 Weeks During Stimulus Conditions

	Stimulus condition											
	Pre-stimulus			Talk			Touch			Talk and touch		
Age	Illness group			Illness group			Illness group			Illness group		
	1	2	3	1	2	3	1	2	3	1	2	3
30	0.9	2.2	0.8	2.4	2.7	1.5	2.5	1.7	0.9	2.2	2.0	1.3
31	1.1	1.1	1.7	0.3	2.2	2.5	0.3	1.8	2.8	1.1	0.2	1.5
32	1.1	2.6	0.4	2.0	3.3	0.9	0.8	2.7	0.6	1.4	1.9	0.8
33	0.8	0.8	2.1	1.3	1.3	4.3	1.0	0.3	2.1	0.9	0.4	2.5
34	0.3	0.1	1.1	2.6	1.4	2.1	1.5	0.7	1.7	0.2	0.7	1.2

Note. Illness groups: 1 = well, 2 = moderately sick, 3 = sick.

Table 5

Mean Heart Inter-beat Interval for Each Illness Group at Postconceptional Ages 30 to 34 Weeks During Stimulus Conditions

	Stimulus condition											
	Pre-stimulus			Talk			Touch			Talk and touch		
Age	Illness group			Illness group			Illness group			Illness group		
	1	2	3	1	2	3	1	2	3	1	2	3
30	.430	.432	.426	.428	.433	.423	.425	.419	.419	.429	.425	.417
31	.419	.424	.414	.415	.415	.423	.413	.419	.407	.406	.428	.414
32	.400	.424	.419	.390	.449	.423	.396	.420	.417	.410	.425	.406
33	.385	.414	.422	.389	.414	.429	.383	.409	.400	.387	.414	.429
34	.391	.398	.402	.390	.396	.405	.387	.412	.399	.402	.404	.406

Note. Illness groups: 1 = well, 2 = moderately sick, 3 = sick.

Table 6

Mean Number of 10-Second Periods with a Smile or Hand-to-Mouth Activity for Each Illness Group at Postconceptional Ages 30 to 34 Weeks During Stimulus Conditions

	Stimulus condition											
	Pre-stimulus			Talk			Touch			Talk and touch		
Age	Illness group			Illness group			Illness group			Illness group		
	1	2	3	1	2	3	1	2	3	1	2	3
30	.40	.17	.08	.47	0	.08	.27	.33	0	.80	.08	.08
31	.33	.08	0	.53	.17	.25	.93	0	.08	.67	.08	.25
32	.93	0	.17	.73	0	.08	.67	.33	.08	.53	.42	0
33	1.00	0	.17	.80	.42	.42	1.00	.50	0	.60	.58	.25
34	.53	.13	.50	.73	.21	.17	.60	.21	.83	.73	.58	.42

Note. Illness groups: 1 = well, 2 = moderately sick, 3 = sick.

Table 7

Mean Number of 10-Second Periods with Any "Avoidance" Signal for Each Illness Group at Postconceptional Ages 30 to 34 Weeks During Stimulus Conditions

	Stimulus condition											
	Pre-stimulus			Talk			Touch			Talk and touch		
Age	Illness group			Illness group			Illness group			Illness group		
	1	2	3	1	2	3	1	2	3	1	2	3
30	.07	.25	.67	.13	.08	.50	.47	.25	1.08	.27	.17	1.08
31	.27	.58	.50	.07	.75	1.00	.20	.25	.75	.27	.50	1.00
32	.47	.42	.83	0	0	.33	.60	.67	.50	.67	.42	1.75
33	.60	.83	.83	.27	.17	.25	.33	.83	.67	.80	.58	1.42
34	.53	.58	.33	.20	.38	.42	.73	.38	.58	1.00	.58	.83

Note: Illness groups: 1 = well, 2 = moderately sick, 3 = sick.

signals) were computed for each pre-stimulus and stimulus condition (see Table 2).

Responses to the talk condition. A 3 x 2 (Illness x Stimulation/Talk) repeated measures analysis of variance revealed a reliable difference in eye movement between the pre-stimulus and the talk condition, $F(1, 11) = 24.38$, $p < .001$. There was more eye opening and eye movement during the talk condition than during the pre-stimulus condition. The mean increase in eye movement for a given talk period was 1; on the average, infants opened or moved their eyes once during the eight 10-second intervals of the pre-stimulus condition and twice during the talk condition. The means also suggest a tendency toward less body movement and less "avoidance" signals during the talk condition, and more smiles and hand-to-mouth activity, although these differences were not statistically significant.

Responses to the touch condition. A 3 x 2 (Illness x Stimulation/Touch) repeated measures analysis of variance revealed a reliable difference in body movement, $F(1, 11) = 53.32$, $p < .001$. Subjects had more body movement during the touch condition than during the pre-stimulus condition. On the average, an infant went from averaging less than one extremity moving per 10-second interval during the comparison period (mean of 7 for 80 seconds) to almost two extremities moving per 10 seconds in the touch condition (mean of 15 for 80 seconds).

Responses to the talk and touch condition. A 3 x 2 (Illness x

Stimulation/Talk and Touch) repeated measures analysis of variance revealed a reliable difference in body movement between the pre-stimulus condition and the combination of talk and touch condition, $F(1, 11) = 83.99$, $p < .001$. Subjects had more body movement during the combination of talk and touch condition than during the pre-stimulus condition. Body movement during the talk and touch condition averaged about 2 extremities moving per 10 seconds (mean of 15 for 80 seconds) as opposed to about 1 extremity moving per 10 seconds during the pre-stimulus condition (mean of 7 for 80 seconds).

Reliable differences in "avoidance" signals between the pre-stimulus and the combination of talk and touch conditions were also found in a 3 x 2 (Illness x Stimulation/Talk and Touch) repeated measures analysis of variance, $F(1, 11) = 15.37$, $p < .01$. There were more "avoidance" signals during the combination of talk and touch condition than during the pre-stimulus condition. There was an average increase of 18 "avoidance" signals when all infants were considered during talk and touch; during the pre-stimulus period the infants showed an average of 33 "avoidance" signals for all the assessments, as opposed to 51 during the talk and touch condition. A given subject might have no avoidance behaviors during the comparison period and 2 or 3 during the combination of talk and touch condition. However, a significant interaction effect of illness with the combination of talk and touch suggested that this effect varied with the illness group, $F(2, 11) = 8.28$, $p < .01$.

Figure 1 depicts the interaction of illness with the stimulus condition of talk and touch; sick infants had substantially more "avoidance" signals during the combination of talk and touch, whereas the moderately ill and well infants showed less difference in the frequency of "avoidance" signals during the pre-stimulus and combination of talk and touch condition.

Illness Effects

Main effects of illness were only seen for two dependent measures: (a) smiles and hand-to-mouth activity and (b) "avoidance" signals.

Smiles and hand-to-mouth activity. There were no significant interactive effects of illness and stimulus conditions with the exception of illness with the combination of talk and touch as noted above. A 3 x 2 (Illness x Stimulation/Talk) repeated measures analysis of variance revealed significant differences among illness groups when the talk condition was compared to the pre-stimulus condition, $F(2, 11) = 12.79$, $p < .01$. Post-hoc comparisons, using the Newman-Keuls procedure, revealed that the well infants had significantly more smiles and hand-to-mouth activity than either the moderately ill group or the sick group; the moderate group had the least number of smiles and hand-to-mouth activity of any illness group and was significantly different from both well and sick infants, $p < .05$.

A 3 x 2 (Illness x Stimulation/Touch) repeated measures analysis of variance condition revealed significant differences among illness groups, $F(2, 11) = 9.69$, $p < .01$, as did the 3 x 2 (Illness x Stimulation/

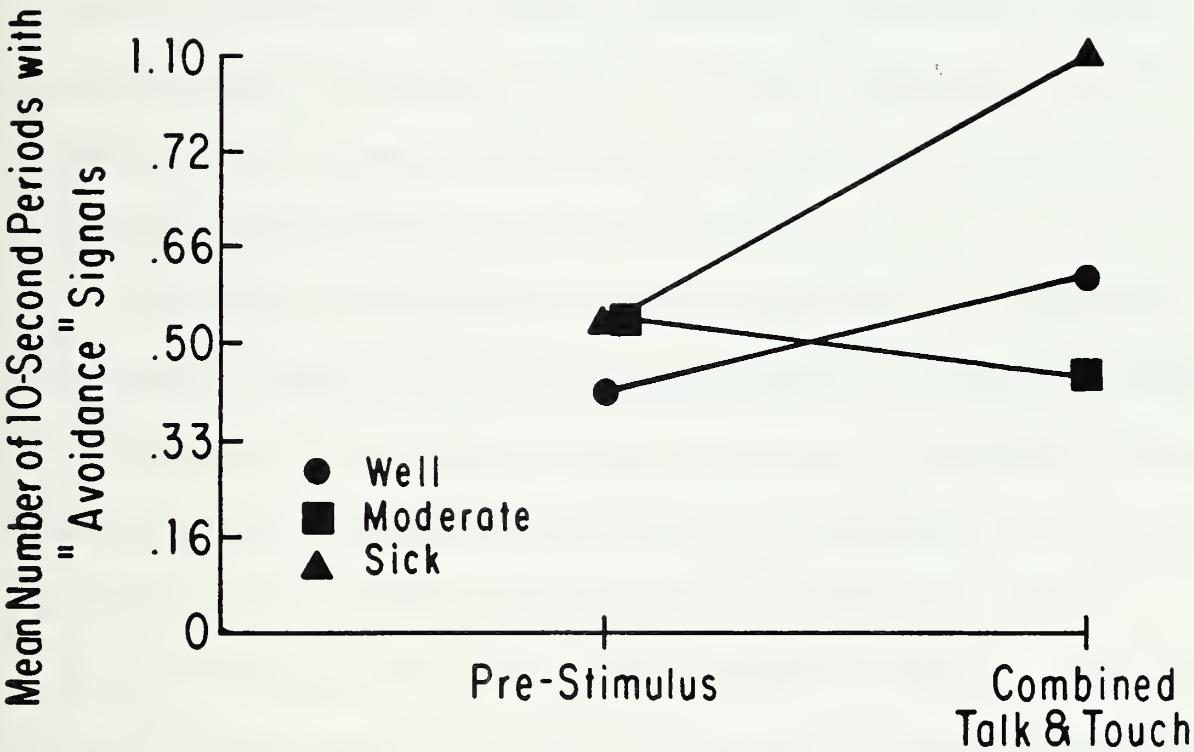

Figure 1. Interaction of stimulus condition (talk and touch vs. pre-stimulus) with illness for "avoidance" signals as the dependent measure.

Talk and Touch) repeated measures analysis of variance, $F(2, 11) = 5.84$, $p < .025$. Post-hoc comparisons, using the Newman-Keuls procedure, revealed that the well infants had significantly more smiles and hand-to-mouth activities than both the sick group and the moderately ill group during touch and the combination of talk and touch, $p < .05$. Moderately ill infants had significantly more smiles and hand-to-mouth activities than sick infants but less than well during the combination of talk and touch but not for touch alone, $p < .05$. Table 2 indicates that, in all conditions, the well infants showed almost three times as frequent smiles and hand-to-mouth activity as the sick infants.

Not only were the effects of illness found in the 3 x 2 (Illness x Stimulation) repeated measures analyses, but they were also found in the 3 x 5 (Illness x Age) repeated measures analyses of variance. The 3 x 5 (Illness x Age) repeated measures analyses of variance revealed significant differences for illness groups for the pre-stimulus condition, $F(2, 10) = 8.14$, $p < .01$; talk condition, $F(2, 10) = 5.29$, $p < .025$; and touch condition, $F(2, 10) = 6.5$, $p < .025$, but not for the talk and touch condition. Table 6 gives the mean smiles and hand-to-mouth activity for each illness group for each age. Post-hoc comparisons using the Newman-Keuls procedure revealed that the well infants had significantly more smiles and hand-to-mouth activities than either the moderately ill or sick infants, and the moderately ill infants did not differ from the sick infants during the pre-stimulus condition. During the talk condition the well

infants again had significantly more smiles and hand-to-mouth activities than either the moderately ill or sick infants; sick infants did not differ from moderately ill infants. During the touch condition, the well infants had significantly more smiles and hand-to-mouth activity than either the moderately ill or sick infants; however, sick infants did not differ from the moderately ill infants.

The 3 x 5 (Illness x Age) repeated measures analysis of variance for the touch condition also showed a significant interaction of illness group and age during the touch condition, $\underline{F}(8, 10) = 3.47$, $\underline{p} < .05$. Figure 2 summarizes the interaction. Although the different age trends are not easily summarized, both sick and well infants showed considerably more activity at week 34 than at week 30, whereas the moderately ill infants did not.

"Avoidance" signals. There were no significant differences among illness groups in "avoidance" signals in the 3 x 2 (Illness x Stimulation) repeated measures analysis of variance. However, as previously noted, there was an interaction of illness group with the stimulus condition of talk and touch, $\underline{F}(2, 11) = 8.28$, $\underline{p} < .01$.

A 3 x 5 (Illness x Age) repeated measures analysis of variance yielded significant differences among the illness groups for the talk condition, $\underline{F}(2, 10) = 4.21$, $\underline{p} < .05$, but not for any other conditions. Inspection of Table 7 shows that the means for well infants during talk were consistently below those of the sick infants. Post-hoc comparisons,

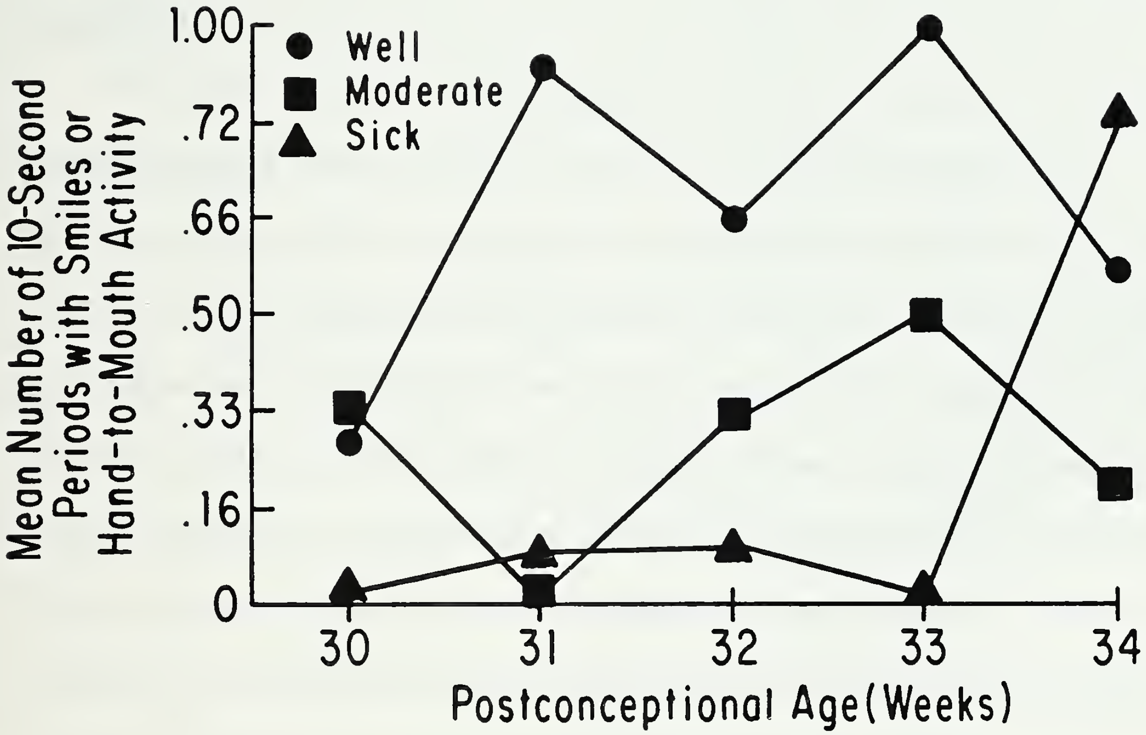

Figure 2. Interaction of illness and postconceptional age for smiles and hand-to-mouth activity as the dependent measure during the touch stimulus condition.

using the Newman-Keuls procedure, revealed significant differences between all three groups during the talk condition: The sick infants had significantly more "avoidance" signals than either moderately ill or well infants; moderately ill infants had significantly more "avoidance" signals than well infants but significantly less than the sick infants, $p < .05$.

Age Effects

The 3 x 5 (Illness x Age) repeated measures analyses of variance with smiles and hand-to-mouth activity as the dependent measures revealed a main effect for age only during the touch condition, $F(4, 10) = 7.99$, $p < .01$. Univariate trend analyses were not significant. As noted in the discussion of illness, there was an interaction of sickness with age, $F(8, 10) = 3.47$, $p < .05$. Figure 2 demonstrates a major increase in smiles and hand-to-mouth activity for sick infants between 33 and 34 weeks, whereas a similar major increase was seen between 30 and 31 weeks for the well infants and no clear age trend was apparent for the moderately ill infants. No other age effects were obtained.

Descriptive Analyses

The analyses so far reported only utilized data from weeks 30 to 34. Data obtained at both earlier and later postconceptional ages were utilized in descriptive analyses to explore further the effects of age and illness. These analyses compared age trends for the two groups of infants most clearly differing in the degree of illness--the sick infants and the well

infants. For the well infants, sufficient data (at least three subjects contributing to the mean for each time period) were available for weeks 30-34; data were averaged for weeks 30 and 31 and then for weeks 32-34. The sick infants also had data for weeks 26-29 and 35-37, so means for those ages were calculated for the sick infants. Comparisons were made for any dependent measure for which there had been effects for stimulus, age, or illness in the main analyses.

Eye Movements

Eye movements were examined during the talk and pre-stimulus conditions because eye movement was significantly greater during the talk condition. Figure 3 presents this comparison. There was some suggestion of developmental changes in that both sick and well infants showed increasing eye movements from age 30-31 to 32-34 weeks. When the pre-stimulus condition was contrasted with the talk condition, both sick and well infants showed a greater increase in eye movement over the pre-stimulus condition at age 32-34 weeks than at 30-31 weeks; however, at 35-37 weeks, the sick infants showed less increase over the pre-stimulus condition than at any other age.

Body Movements

Body movements during touch and the combination of talk and touch conditions were examined because body movement was greater during these stimulus conditions. Figure 4 depicts body movement during the

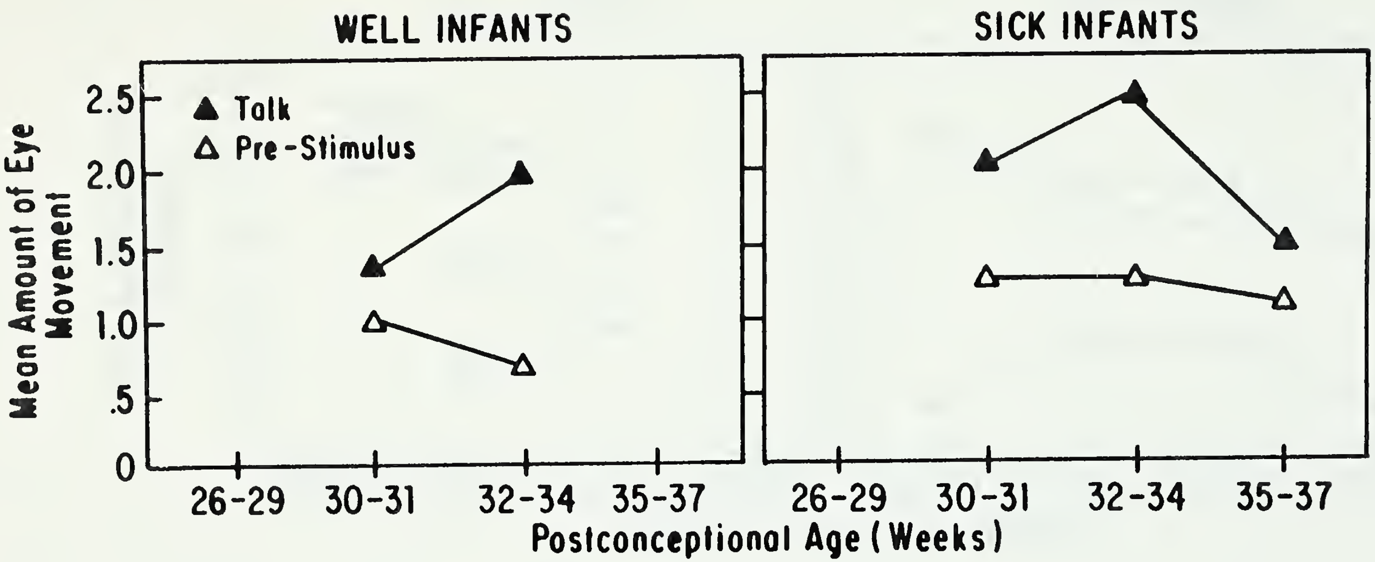

Figure 3. Mean amounts of eye movement during the pre-stimulus and talk conditions as a function of postconceptional age for sick and well infants.

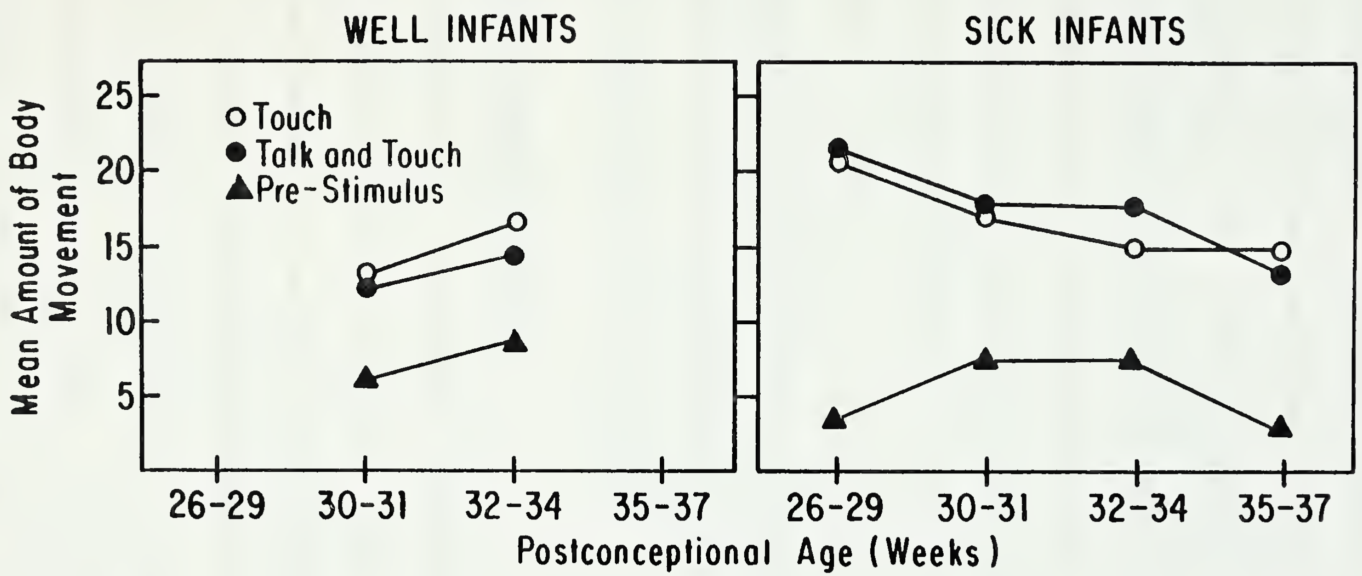

Figure 4. Mean amounts of body movement for touch, talk and touch, and pre-stimulus conditions as a function of postconceptional age for sick and well infants.

touch, the combination and talk and touch, and the pre-stimulus conditions. With increasing age, well infants increased their body movement during the pre-stimulus as well as during the touch and combination of talk and touch conditions. For well infants, there was only a slightly greater increase in body movement to the touch condition over the pre-stimulus condition at ages 32-34 than at ages 30-31 weeks. A quite different developmental pattern was found for sick infants, who showed their greatest amount of body movement and greatest increase over the pre-stimulus condition occurring at the earliest ages, 26-29 weeks. By 32-34 weeks, the amount of body movement shown by the sick infants had decreased during touch and increased during the pre-stimulus period to a level roughly comparable to the well infants.

Smiles and Hand-to-Mouth Activity

Figure 5 depicts smiles and hand-to-mouth activity for the pre-stimulus and for all the stimulus conditions. Well infants increased the number of smiles and hand-to-mouth activity during the talking alone and touching alone conditions with increasing age; but the frequency decreased slightly for the combination of talk and touch. Further, well infants had more smiles and hand-to-mouth activity during the stimulus conditions than the pre-stimulus condition at 30-31 weeks; however, they had fewer such activities during stimulus conditions than during the pre-stimulus condition at 32-34 weeks.

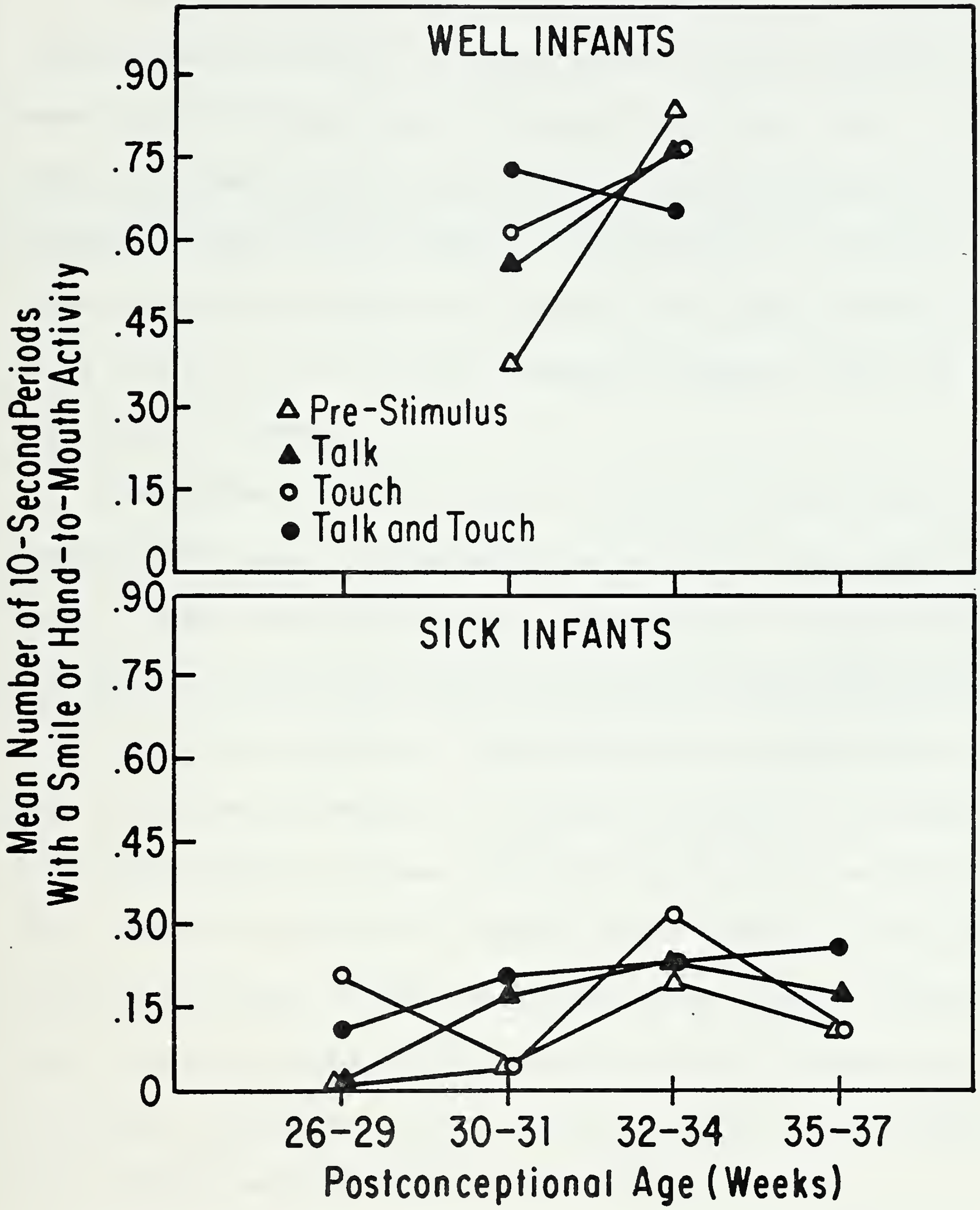

Figure 5. Mean number of 10-second periods with smiles or hand-to-mouth activity during each stimulus condition as a function of post-conceptional age for sick and well infants.

The sick infants had very few smiles and hand-to-mouth activity although a tendency toward increasing numbers of smiles and hand-to-mouth activity with age is apparent through 32-34 weeks. Still, at 32-34 weeks the number of smiles and hand-to-mouth activity of the sick infants averaged less than half the number for the well infants. For the sick infants, there was a tendency at all ages for more smiles and hand-to-mouth activity to occur during the stimulation conditions rather than the pre-stimulus condition.

The combined category of smiles and hand-to-mouth activity was divided into the component behaviors in order to more fully explore the nature of illness and age differences. Totals for each category during each stimulus condition for weeks 30 to 34 postconceptional age were done. Table 8 gives the frequencies of smiles and hand-to-mouth activity for each of the stimulus conditions for sick and well infants. Well infants had a total of 37 smiles for all observations (during a total of about 80 minutes), whereas sick infants had a total of only 11 smiles. The major difference in the number of smiles was during the pre-stimulus and talk conditions where well infants had three times the number of smiles as the sick infants. During the touch and combination of talk and touch conditions, both sick and well infants had few smiles.

There were also differences in hand-to-mouth activity. Well infants had a total of 161 hand-to-mouth activities; in contrast, the sick infants had a total of only 52. There were more hand-to-mouth activities than

Table 8

Total Frequency of Smiles and Hand-to-Mouth Activity for Sick and Well Infants During Each Stimulus Condition During 30 to 34 Weeks' Post-conceptional Age

	Stimulus condition			
	Pre-stimulus	Talk	Touch	Talk and Touch
Well				
Smiles	12	19	1	5
Hand-to-mouth	35	32	49	45
Sick				
Smiles	1	6	1	3
Hand-to-mouth	12	10	18	12

smiles for both sick and well infants; and, in contrast to smiles, well infants had almost three times the hand-to-mouth activities for all the stimulus conditions.

Both smiles and hand-to-mouth activity increased with age through week 34 for both sick and well infants. Sick infants showed a decrease in these activities at 35-37 weeks' postconceptional age.

"Avoidance" Signals

Figure 6 depicts "avoidance" signals for the pre-stimulus and stimulus conditions. Sick infants had more "avoidance" signals to stimuli than the well infants except at 32-34 weeks when the response to the touch condition was similar to the well infants. There was also a suggestion of different changes with stimulus conditions for the sick versus well infants. For sick infants there was a consistent increase in "avoidance" signals over the pre-stimulus condition during the talk, touch, and the combination of talk and touch conditions except for weeks 32-34. A quite different pattern was evident for the well infants. The well infants had considerably fewer "avoidance" signals during talk (less than the pre-stimulus condition) but did show increased "avoidance" signals to touch and the combination of talk and touch both at weeks 30-31 and 32-34.

The four components of the category of "avoidance" signal were examined to explore further the nature of illness and age differences. Table 9 gives the frequencies of each component of "avoidance" signals

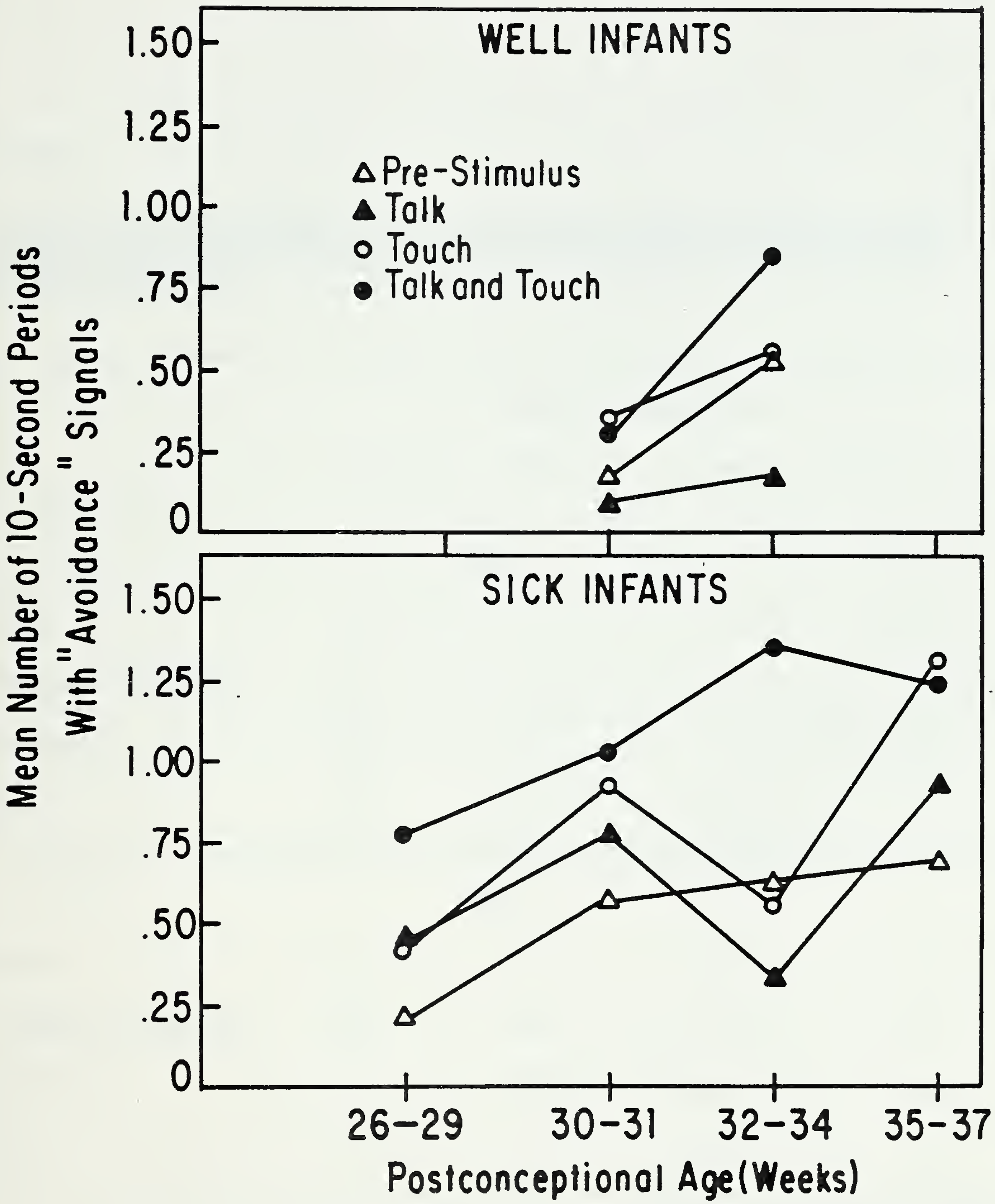

Figure 6. Mean number of 10-second periods with "avoidance" signals during each stimulus condition as a function of postconceptional age for sick and well infants.

Table 9

Total Frequency of Each Type of "Avoidance" Signal for Sick and Well Infants During Each Stimulus Condition During 30 to 34 Weeks' Post-conceptional Age

	Stimulus condition			
	Pre-stimulus	Talk	Touch	Talk and Touch
		Well		
Yawn	6	1	6	11
Tongue protrusion	3	2	8	5
Grimace	18	8	13	26
Cry	6	0	11	7
		Sick		
Yawn	1	4	3	5
Tongue protrusion	22	22	19	33
Grimace	17	10	22	42
Cry	6	0	4	9

for each stimulus condition during 30-34 weeks' postconceptional age for both sick and well infants. Grimaces were a frequent "avoidance" signal and occurred most often during the combination of talk and touch condition for both sick and well infants. Sick infants, however, had more tongue protrusion than the well infants; slightly more occurred during the combination of talk and touch than during other stimulation conditions. Although the frequency was slightly greater for well infants, yawns and cries occurred infrequently for both sick and well infants and were slightly greater for the combination of talk and touch condition. It was expected that sick infants would have less cries since they were more often intubated, preventing them from being heard. Although not shown in Table 9, both sick and well infants tended to increase grimaces, cries, and, to a lesser extent, yawns with increasing age. Tongue protrusions mainly occurred for sick infants and did not show a tendency to increase with age.

In summary, examination of data from the full range of postconceptional ages revealed hints of developmental change as well as illness effects. In regard to developmental changes, both sick and well infants showed increased eye movement with increasing gestational age to the talk condition with the greatest increase over the pre-stimulus condition coming at 32-34 weeks. Further, well infants showed increasing body movement with increasing age during the pre-stimulus condition, the touch condition, and the combination of talk and touch condition. In

contrast, sick infants had their greatest amount of body movement and the greatest increase over the pre-stimulus condition at 26-29 weeks. Both sick and well infants had increasing smiles and hand-to-mouth activity with increasing age through week 34; however, sick infants showed a decrease in these activities at 35-37 weeks. When smiles and hand-to-mouth activity were counted separately, they both increased with increasing gestational age except that sick infants did not continue to increase at 35-37 weeks. "Avoidance" signals also tended to increase with increasing gestational age, particularly for the combination of talk and touch condition for both sick and well infants.

In addition to illness differences noted above, the major differences between sick and well infants were in the number of smiles, hand-to-mouth activity, and "avoidance" signals. Well infants had considerably more smiles and hand-to-mouth activity, and sick infants had more "avoidance" signals.

Other Evidence of Developmental Change and Sickness Effects

Further evidence of developmental change and the effects of illness was obtained from the weekly neurological and behavioral exam performed by the principal investigator. No inter-examiner reliability was assessed for this exam, and hence the results should be viewed as tentative. It is possible the examiner was biased since the degree of illness of the infant was obvious and the administration of these exams varied as a function of

illness and medical treatment. Figures 7 and 8 depict the performance of both sick and well infants on the five Brazelton Neonatal Behavioral Assessment Scale orientation items which rank responsiveness to the presentation of: animate (human face) and inanimate (red ball) visual stimuli, animate (talking) and inanimate (sounding of a bell) auditory stimulation, and to the combination of human face and talking. These items were completed for most of the well subjects from week 31 to week 35. The five well infants showed improving performance with age in response to all of the orientation items. The moderately ill and severely ill infants were not able to be tested as readily because of the severity of their illness, and group data are only depicted for weeks 33 to 36. These infants showed poorer performance on some stimuli than the well infants and decreased performance with age after 34 weeks in contrast to the continuing improved performance of the well infants.

The neurological part of the exam offered still further information about developmental change and illness effects. The infants' responses to all the reflexes tested increased in completeness over time (see Appendix C for scale). For example, palmar grasp progressed from incomplete flexion of the fingers at 28 weeks to full flexion for greater than 10 seconds by week 36.

Some reflexive responses varied little with illness. Plantar and palmar grasp and rooting reflexes appeared to vary little with the degree of illness. All infants had a plantar grasp; by 36 weeks all three illness

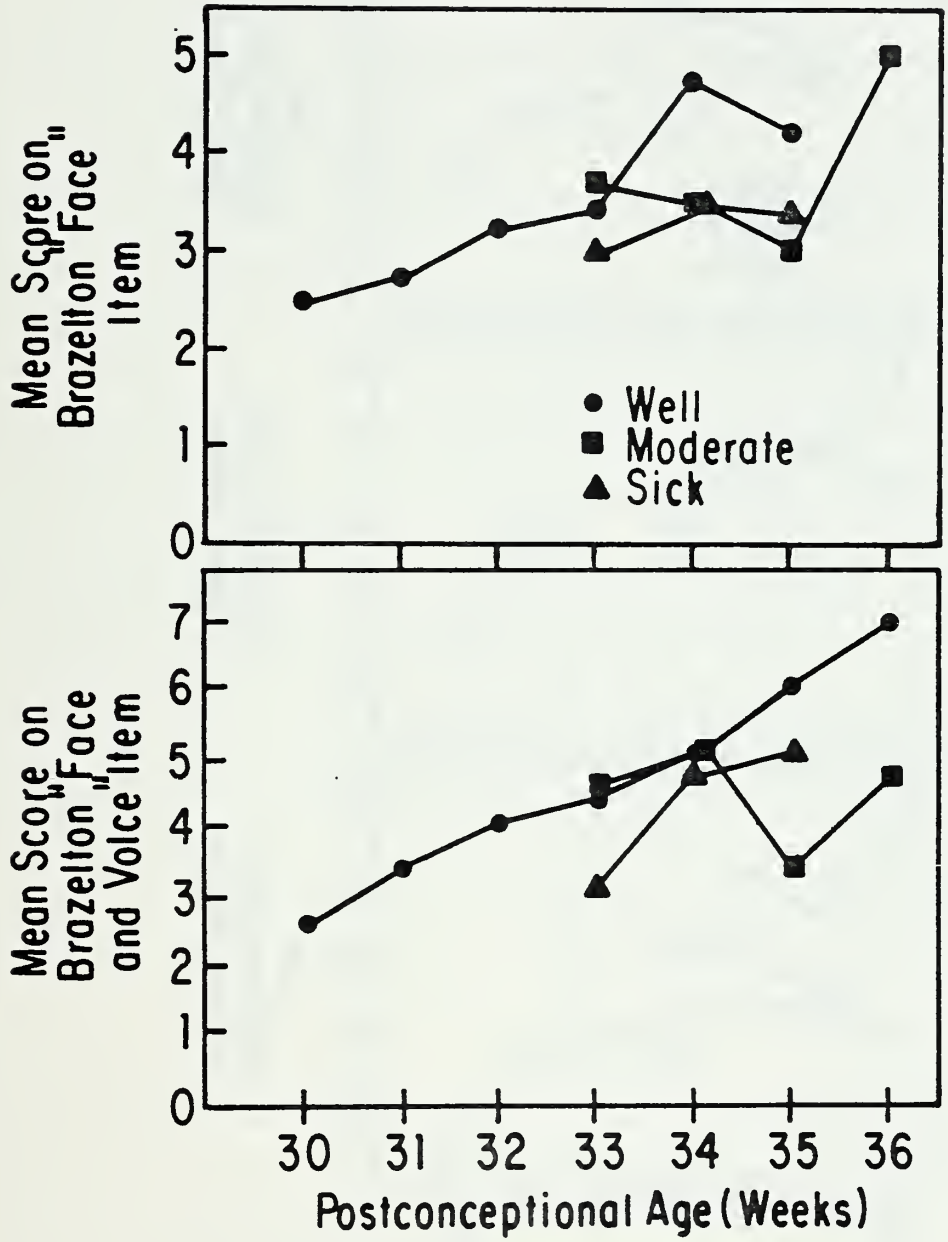

Figure 7. Changes with postconceptional age in mean scores on Brazelton "Face" and "Face and Voice" items.

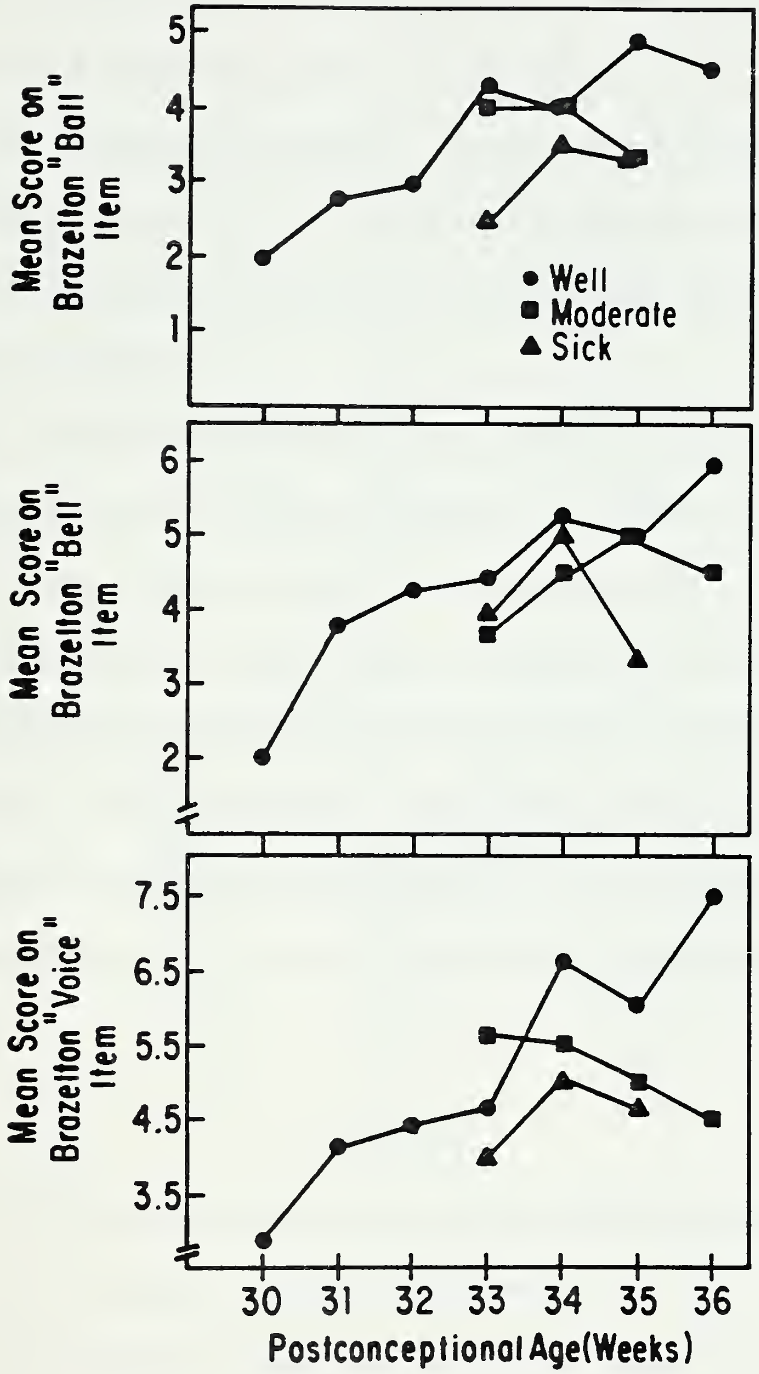

Figure 8. Changes with postconceptional age in mean scores on Brazelton "Ball," "Bell," and "Voice" items.

groups were scoring a 2 for rooting, and by 36 weeks all groups were scoring around 4 for palmar grasp. Incurvation, when condition permitted eliciting, was present in all infants. A score of 3 was obtained for placing by all infants by about 33 to 34 weeks. Automatic walking was not elicited until 35 weeks in any infant. Acoustic blink was present by 30 weeks in most infants.

Other reflexive responses did vary with the degree of illness. For the Moro, head control, traction response, and ventral suspension, the well infants scored higher than the sickest infants and, in most cases, the moderately ill infants as well. Figure 9 depicts these differences in performance. The scores of all infants for head lift in the prone position and lower body tone were similar. The sickest infants exhibited slightly less upper body tone than the moderately ill or well infants. The sickest infants consistently, i.e., at every age, had more spontaneous body movement.

Summary

The results of the repeated measures analyses of variance showed that each of the stimulus conditions (talk, touch, and the combination of talk and touch) elicited a significant behavioral response from these immature infants. During talk there was significantly more eye movement than during the pre-stimulus condition; during touch there was significantly more body movement; during the talk and touch condition there was

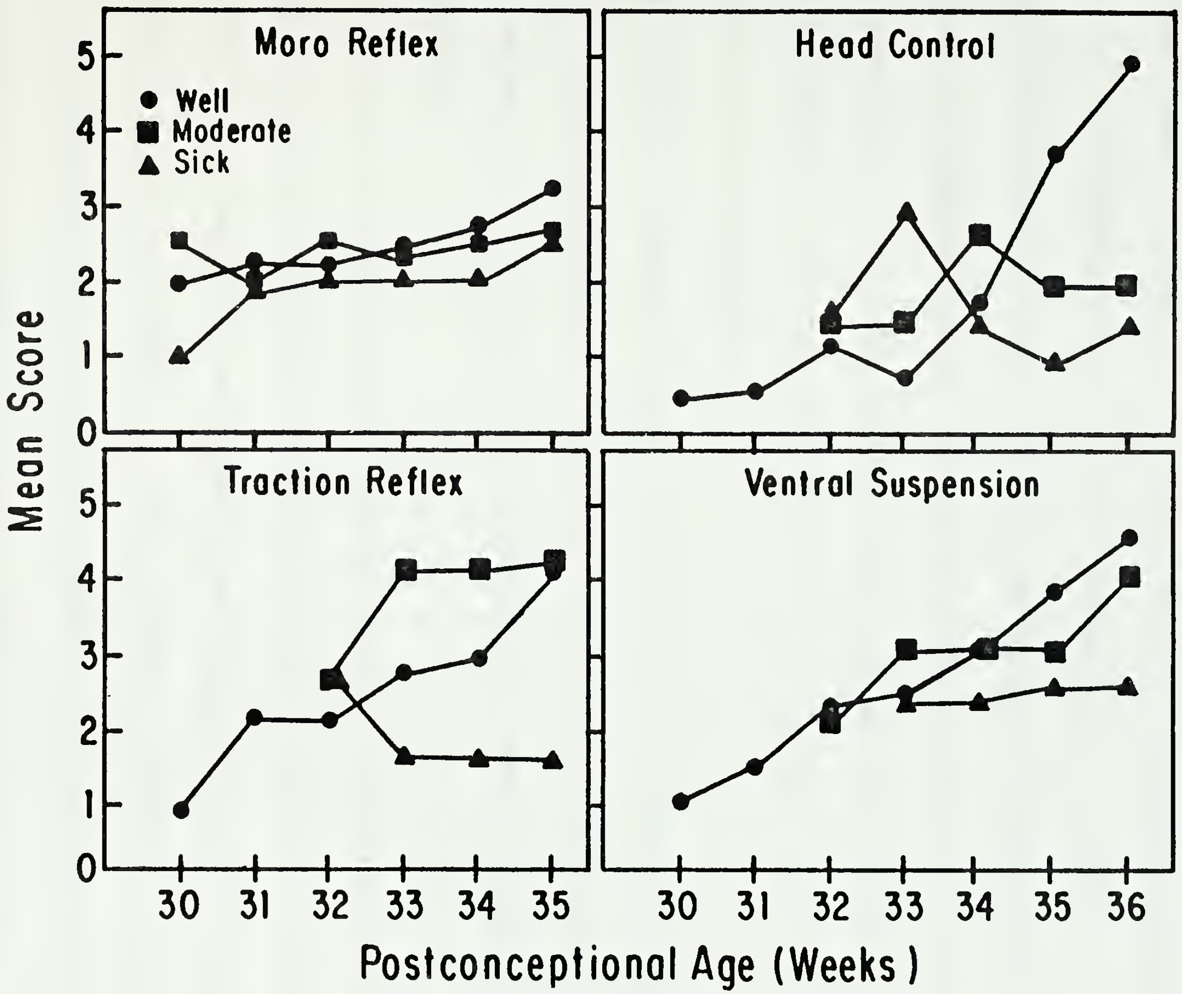

Figure 9. Changes with postconceptional age in mean scores on selected neurological exam items.

significantly more body movement and "avoidance" signals (yawns, grimaces, tongue protrusion, and crying).

The effects of sickness were most evident when smiles and hand-to-mouth and "avoidance" signals were the responsiveness measure. Well infants showed significantly more smiles and hand-to-mouth activity in all the stimulus conditions than the sick infants. Well infants had reliably fewer "avoidance" signals during talk; there was also an interactive effect of illness with the combination of talk and touch with sick infants having the most "avoidance" signals.

The only main effect of age was found in the 3 x 5 (Illness x Age) repeated measures analysis of variance for the touch condition where smiles and hand-to-mouth activity (combined) increased in frequency with increasing age.

Sufficient data were available only for weeks 30 to 34 postconceptional age for the well infants. Examining the mean scores for the well infants for the pre-stimulus and stimulus conditions led to the following descriptive statements. During the talk condition, well infants showed less body movement, fewer "avoidance" signals, more smiles and more eye movement, and a similar frequency of hand-to-mouth activity. During the touch condition, they showed increased body movement, more "avoidance" signals, more eye movement, more hand-to-mouth activity, and fewer smiles. Finally, in the talk and touch condition, they showed more body movement, more "avoidance" signals, more eye movement,

more hand-to-mouth activity, and fewer smiles. Very little change in heart rate occurred in any stimulus condition. With increasing age (30-31 weeks vs. 32-34 weeks), well infants showed: (a) more eye movement, more smiles, and more hand-to-mouth activity during the talk condition; (b) more body movement, more hand-to-mouth activity, and more "avoidance" signals during the touch condition; and (c) more body movement and more "avoidance" signals during the combination of talk and touch condition.

Sufficient data were available for both earlier (26-29 weeks) and later (35-37 weeks) postconceptional ages for the sick infants. Comparing the pre-stimulus and stimulus conditions for weeks 30-34 postconceptional age, sick infants showed patterns of response to talking and touching similar to those of well infants. Like the well infants, during the talk condition they showed more eye movement, more smiles, less body movement, and about the same frequency of hand-to-mouth activity; however, unlike the well infants, they showed more "avoidance" signals. During the touch condition, sick infants were like the well infants in that they had more body movement, more eye movement, more "avoidance" signals, and more hand-to-mouth activity; however, they differed in that they had the same number of smiles as the pre-stimulus condition. Sick infants were like well infants during the combination of talk and touch condition in that they had more body movement, more eye movement, and more "avoidance" signals; however, they were different in that hand-to-mouth activity and smiles were similar to the pre-stimulus condition.

Patterns of response were somewhat different for the younger ages, 26-29 weeks. It was not possible to compare eye movement since most infants had their eyes covered for phototherapy at these ages. No smiles occurred either in the pre-stimulus or stimulus condition. Activity during the talk condition differed in that there was more body movement and more hand-to-mouth activity; however, like weeks 30-34 for the sick infants, there were more "avoidance" signals. For the touch condition, the pattern was the same as weeks 30-34 with more "avoidance" signals, more hand-to-mouth activity, and even more body movement than at weeks 30-34. During the combination of talk and touch condition, the pattern was similar to 30-34 weeks with more "avoidance" signals, even more body movement than at weeks 30-34, and about the same frequency of hand-to-mouth activity.

At the older ages, 35-37 weeks, the pattern of responding was also different and, in general, there was less activity. There were fewer smiles and hand-to-mouth activity and less body and eye movement, yet "avoidance" signals remained the same as at other ages or were even greater depending on the stimulus condition. During the talk condition, the response pattern was more similar to the younger ages with more eye movement, more body movement, more hand-to-mouth activity, more "avoidance" signals, and no change in smiles. For the touch condition the response pattern was similar to other ages with more body movement, more hand-to-mouth activity, more "avoidance" signals, and fewer smiles;

however, there was less eye movement. During the combination of talk and touch condition, there was more body movement and "avoidance" signals, and little change in smiles as with other ages; however, there was more hand-to-mouth activity and eye movement did not change.

When the entire range of ages was considered, there was a pattern suggestive of decreasing activity during stimulus conditions except for "avoidance" signals. With increasing age, sick infants showed: (a) less eye movement, about the same frequency of body movement, more "avoidance" signals, fewer smiles, and slightly fewer hand-to-mouth activities during the talk condition; (b) less eye movement, less body movement, fewer smiles, fewer hand-to-mouth activities, and more "avoidance" signals during the touch condition; and (c) less eye movement, less body movement, fewer smiles, slightly more hand-to-mouth activity, and more "avoidance" signals. Further, sick infants differed from well infants in that their performance on the Brazelton orientation items and selected neurological reflexes was poorer than that of the well infants. Further, their performance on the Brazelton "voice," "bell," and "ball" items became somewhat poorer after 34 weeks rather than improving.

CHAPTER IV

DISCUSSION

Preterm infants as young as 30 weeks' postconceptional age showed different systematic patterns of response to being talked to and to being stroked. When they were talked to, they opened and moved their eyes reliably more often than during a period of nonstimulation. On the average, they also showed less gross body movement and fewer "avoidance" signals, although these differences were not statistically reliable. When touched (stroked) they moved their extremities reliably more than during the nonstimulation period. Further, they also opened their eyes more and showed more "avoidance" signals; however, these differences were not statistically reliable. Talking combined with touching produced a response similar to touching alone, with all the infants showing reliably more body movement and sick infants showing more avoidance signals.

These systematic patterns of response to talking and touching were seen in preterm infants of all postconceptional ages studied. The only reliable developmental change in responsiveness to talking and touching was an increase in smiles and hand-to-mouth activity (considered together) during touching. The paucity of reliable changes with age contrasts sharply

with the initial expectations of developmental change to all stimulus conditions. Although we know that the nervous system is changing rapidly during the ages studied and that these infants' responses on the Brazelton orientation items and to several neurological reflexes were changing, few behavioral changes were detected in the pattern of responsiveness to talking and touching.

There were, however, hints of developmental change seen in the descriptive analyses. Contrasting weeks 32-34 with weeks 30-31, for example, suggested that eye movement increased during talking; body movement increased during touching and the combination of talking and touching, and smiles/hand-to-mouth activity and "avoidance" signals were greater during all stimulus conditions for both sick and well infants. At still later ages (35-37 weeks) sick infants showed a decrease in all these activities except for "avoidance" signals. Further, sick infants showed their greatest increase in body movement to touching and the combination of talking and touching at the youngest ages studied (26-29 weeks). The hints of developmental change in the well infants suggest that reliable developmental changes might be obtained if a larger sample of well infants were assessed. Still, the similarity in response to talking and touching across 30 to 34 weeks is substantial. The more complex developmental changes suggested by the data from the sick infants are difficult to consider in the absence of comparable data for well infants. Only questions can be raised. Is the very immature infant hyper-responsive to tactile

stimulation? Is the decrease in responsiveness at later ages (35-37 weeks) for the sick infants a normative developmental change, or may it reflect decreased responsiveness as a result of specific intensive care nursery experience or damage to the central nervous system causing interference with responsiveness?

During postconceptional weeks 30 to 34, few reliable differences were detected in how the sick versus well infants responded to talking and touching. Unlike the initial prediction that sick infants would be less responsive to talking and "hyper-responsive" to touching, sick infants showed reliably increased eye opening and eye movement during talking and increased gross body movement during touching and the combination of talking and touching that did not differ from that of well infants. Sick infants, however, did present a somewhat different behavioral picture. They smiled less and showed less hand-to-mouth activity during all stimulus conditions and reliably more "avoidance" signals than the well infants during talking, suggesting that even the mildest stimulation elicited more "avoidance." Sick infants also showed the most "avoidance" during the combination of talking and touching, suggesting that stimulation in two sensory modalities was the most aversive.

Even the youngest and sickest babies showed a variety of behaviors. They smiled, brought their hand to their mouth, grimaced, stuck out their tongues, yawned, cried, opened and moved their eyes, and moved their extremities. The presence of these behaviors suggests that even the

youngest babies studied may be capable of expressing displeasure to others, of attempting to stabilize their own behavior when faced with stimulation, and of orienting and attending to some social stimuli.

Striking was the fact that these infants responded to the social stimuli of talking and touching in ways similar to those described for full-term infants. Unfortunately, there are few studies which have directly assessed the behavioral responsiveness of newborn infants to social stimuli. Studies of responsiveness to tactile stimulation in the form of responsiveness to touching with a plastic filament have revealed that infants of 38 weeks' postconceptional age responded with increased body movement and heart rate acceleration (Field et al., 1979; Friedman et al., 1981; Rose et al., 1976). Missing are studies of human newborn infants' behavioral responsiveness to stroking.

Fullterm infants have been noted to turn toward a continuous sound source (Muir & Field, 1979) and to decrease body movement, increase eye movement, and turn toward the sound of a voice (Brazelton, 1973). Infants of 36 weeks were noted to decrease their heart rate in response to a taped recording of their mothers' voice (Segall, 1972). No reliable changes in heart rate to talking or stroking were obtained in the present study, but the changes in body movement and eye movement obtained correspond to those described for fullterm infants.

The behavioral changes of eye opening and moving and gross body movement documented here also correspond to behaviors that others have

shown both attract the caregiver and guide the caregiver's activity with the infant. Als (1983) concluded from her observations of 41 fullterm infants and mothers that infant eye opening and movement and motor movement consistently led to maternal behaviors. For example, when the infant's eyes were open, eye contact with the mother tended to occur. Further, physical (motor) activity on the part of the infant also led to action on the part of the mother in the form of holding and looking. She speculated that both mother and infant at birth are "regulated" to bring about early mutual acknowledgment. Further, Marton, Minde, and Ogilvie (1981) found, in sequential analyses of mothers and their preterm infants, that an infant's gross motor stretch (arm, leg, or head movement) was likely to elicit a smile from high-activity mothers (mothers that exhibited the most activity during nursery visits). When an infant's eyes were open, the mother was likely to be touching the infant.

Although the present study has largely explored hitherto unexplored areas concerning the responsiveness of preterm infants to social stimuli, how consistent are its findings with other information we have about preterm infants? The findings of increased body movement to touching are consistent with other studies. Both ultrasound examinations of the fetus (de Vries et al., 1982; Ianniruberto & Tajani, 1981) and the clinical observations of Gesell (1952) and Saint-Anne Dargassies (1977) suggest that by 26 weeks or less following conception the infant is capable of moving in response to tactile stimulation. In regard to responsiveness of preterm

infants to touching of a social nature, stroking, we know little. Minde et al. (1983) reported that both sick and well infants exhibited eye and body movement during interaction with their mothers who were talking or touching; however, there was no attempt to relate the amount of infant body movement directly to the mother's talking or touching or to compare it with a period without such stimulation.

Similarly, the findings of increased eye movement are not inconsistent with those of other studies. We know that as early as 30 weeks' post-conceptional age infants can fixate on high figure-ground contrast and sharp contour patterns (Hack et al., 1981). Infants of 28 weeks have been observed to have their eyes open (Prechtl et al., 1979). Minde et al. (1983) found that preterm infants opened their eyes during interactions with their mothers.

Hand-to-mouth activity appears to be a method of stabilization which allows the infant to continue to respond or alert to stimuli (Als & Brazelton, 1981; Brazelton, 1973). In the present study, sick infants showed reliably less smiling and/or hand-to-mouth activity during all the stimulus conditions. Well infants utilized hand-to-mouth activity three times more often than sick infants, perhaps suggesting that well infants were more able to stabilize themselves in the face of stimulation. It seems unlikely that the well infants were just more responsive, since both their eye and body movements in response to stimulation were similar to those of sick infants. A cautionary note must be added, however: Hand-

to-mouth activities by the sick infants may have been influenced by the fact that they were more often restrained; and, even though the infants' efforts to reach the mouth were credited, the restraints may well have inhibited the infants. Both sick and well infants showed less hand-to-mouth activity during talking than during other stimulus conditions, suggesting that infants had less need for these behaviors during this type of stimulation. In contrast, both sick and well infants showed more hand-to-mouth activity during touching and the combination of talking and touching, suggesting that these stimuli called for stabilizing behaviors.

Smiling is known to occur in preterm infants and has interested investigators for some time (Emde, Gaensbauer, & Harmon, 1977; Emde & Harmon, 1972; Wolff, 1966). Wolff (1966) concluded that neonatal smiling occurred spontaneously but also in response to mild auditory and visual stimulation during drowsy sleep states. Smiling in infants of less than 44 weeks' postconceptional age has been called "endogenous" and felt to be associated with the rapid eye movement (REM) state mediated through the brainstem (Emde & Harmon, 1972). Smiling was found to occur 17 times per 100 minutes of REM sleep in fullterm infants and about 4 to 5 times that frequently in preterm infants; and this increased frequency of smiling in preterm infants was thought to reflect the lessened maturation of their cerebral cortex and hence less neurological inhibition (Emde & Harmon, 1972). In the present study, well premature infants had a total of 12 smiles during the pre-stimulus period (20 minutes), which would be the

equivalent of 60 smiles in 100 minutes, a figure similar to the 4 to 5 times the fullterm estimate of Emde and Harmon (1972). However, since there are no similar figures for smiles to social stimuli in the literature, the meaning of the present findings is unclear. Both sick and well infants smiled more during talking and less during touching, suggesting that talking somehow stimulated smiling whereas touching did not. Possibly touching may have induced a more alert state inconsistent with endogenous smiling.

Sick premature infants in the present study showed substantially fewer smiles (about 75% fewer) than the well infants. Perhaps the fewer smiles for the sick infants means that they were less often in a drowsy REM state. The findings of Holmes et al. (1979) are of particular interest in light of the paucity of smiles in sick infants; they found that preterm infants on ventilators had more active sleep and less quiet sleep than premature infants of similar postconceptional age without medical complications. Similarly, Karch et al. (1982) found that preterm infants on ventilators showed distinct reduction in periods of wakefulness and an increase in indeterminate sleep felt to reflect impairment in central nervous system function. Since smiles are known to occur during REM sleep state, less REM sleep might be expected to be associated with less smiles. However, it has been the clinical observation of this author that smiles also occur when the infant is in what appears to be a fully alert state, particularly around feeding.

Not only were the very immature infants of the present study able to utilize stabilizing activities and smiles, they demonstrated their ability to signal displeasure through "avoidance" signals such as grimacing, tongue protrusion, yawning, and crying. All of these behaviors have been thought of as ways the infant has of reflecting sensory overload (Als, 1983; Gorski, Davison, & Brazelton, 1979). "Avoidance" signals were significantly more frequent during the combination of talking and touching; however, the interaction of illness with this stimulus revealed that it was the sick infants who accounted for this effect, suggesting that the combination of these two stimuli was "overloading" to the sick infants. These findings of increased "avoidance" signals during the combination of talking and touching support the conclusion of Gorski et al. (1979), who felt that the immature infant can only take in a small amount of stimulation and only in one modality; and only gradually is she/he able to take in two or more stimuli presented simultaneously. The results of the present study, however, indicate that it is the sick infants who have difficulty with multi-modal stimuli. In contrast, "avoidance" signals tended to decrease in frequency during talking, particularly for the well infant. Sick infants, too, showed fewer "avoidance" signals during talking except for the yawning. Thus, talking appeared to be tolerated better by well and sick infants.

The paucity of significant differences between well and sick infants in responsiveness to talking and touching contrasts with the findings on the neurological and Brazelton orientation items. Poorer performance by the sick infants on several of these items suggests that the infant's nervous

system was affected by illness and/or that illness in some way lessened their ability to respond. With one exception (Minde et al., 1983), no other studies have compared the behaviors of well infants with sick infants during talking and touching for the ages assessed in the present study. Minde et al. found that sick infants had less body movement than well infants during interactions with their mothers during the early part of their hospitalization. This finding has not been replicated in the present study; however, unlike the present study, no attempt was made to code the infant's response to a controlled amount of talking and touching. Further, interactions with the mothers lasted up to 40 minutes in contrast to the 80-second periods in the present study which totaled less than 5 minutes.

Other studies at different postconceptional ages have also found lower scores on the Brazelton orientation items for sick preterm infants (Divitto & Goldberg, 1979; Holmes et al., 1982; Kurtzberg et al., 1979). Divitto and Goldberg (1979) tested infants at the time of discharge and 10 days following discharge and reported significant differences between sick preterm infants, healthy preterm infants, and healthy fullterm infants on optimal scores on the animate visual item (face), inanimate visual item (ball), and the combination of face with talking. Sick infants scored lower on the items assessing visual responsiveness. Holmes et al. (1982) also contrasted four groups: preterm infants with mild or moderate respiratory distress syndrome, fullterm infants who stayed in the intensive care nursery for medical complications, healthy fullterm infants, and fullterm

infants who had an extended hospital stay secondary to their mothers' postpartum complications. They found that illness had significant effects on the Brazelton interactive process cluster (orientation items plus quality of alertness, ease of consoling, and cuddliness); sick infants, whether fullterm or preterm, showed a poorer quality behavior than well preterm infants. In contrast, Sostek, Quinn, and Davitt (1979) found no differences between healthy preterm infants, ill preterm infants, and preterm infants with central nervous system problems, and fullterm infants on the Brazelton interactive process cluster.

Similarly, the findings of the less mature or less developed responsiveness on related neurological exam items (Moro, head control, traction, pull-to-sit, and ventral suspension) are also consistent with other studies. Both Holmes et al. (1982) and Sostek et al. (1979) found that the performance of preterm infants on the Brazelton motoric processes cluster (reflexes, activity, motor maturity, muscle tone, hand-to-mouth activity, coordination and defensive movements) was poorer than that for fullterm infants. Further, performance was poorest for the preterm infants who had been ill or had experienced central nervous system insult (Sostek et al., 1979). Another study which assessed neurological function of preterm infants found that ill infants scored the poorest on the traction or pull-to-sit response, suggesting decreased muscle tone and a delay in motor development (Fox & Lewis, 1981). Similarly, preterm infants (28-37 weeks at birth) with respiratory distress syndrome were

tested at irregular intervals and found to have poor muscle tone; they did not assume a head-right position even at 39 weeks, suggesting that motor development was affected by illness (Lewkowitz et al., 1979).

In contrast to the prediction that heart rate would either increase or decrease in response to stimulation, no significant changes in heart rate occurred in the present study. The technique used to determine heart rate may not have been sufficiently sophisticated in that heart rate had to be punched into the computer for calculation and thus was more subject to human error. It is, however, also possible that the infants in the present study were not sufficiently mature for a heart rate deceleration or acceleration to a specific stimuli to occur. Since few studies document cardiac responsiveness in preterm infants, the lack of cardiac change in the present study is unclear. Only one study of similarly aged preterm infants has reported a change in heart rate (Polikanina & Probatova, 1965). The degree of illness of the preterm infants, however, was not specified, and the stimuli presented (electric bell, a tone, and a light) were not social stimuli. However, studies which assessed cardiac change in infants of 37 weeks' postconceptional age (Rose, 1983; Schmidt et al., 1980) did not find changes in heart rate to tactile stimulation. In fact, Rose (1983) found that preterm infants did not respond ever to the strongest tactile stimulation provided by a plastic filament. In testing done at 36-38 weeks' postconceptional age, low-risk preterm infants showed cardiac acceleration, but high-risk infants failed to demonstrate reliable cardiac changes

to auditory stimulation in the form of a rattle (Krafchuk, Tronick, & Clifton, 1983). Segall (1972), in testing preterm infants of 36 weeks' postconceptional age, found heart rate deceleration to their mothers' voices. In the present study, cardiac data were only available for the well infants only at the youngest ages because cardiac monitoring was discontinued for three of the five subjects by 32 weeks' postconceptional age; only the sick infants had data through 37 weeks' postconceptional age.

How can we use the information gained from the present study to counsel parents and other caregivers? At the very least parents can be informed that the premature infant--even the youngest and sickest infant--responds to social stimuli which parents can easily provide: talking and touching. Further, we can use our knowledge to demonstrate to parents the behaviors which infants exhibit in response to these stimuli, as a further means of enhancing their understanding of the interactive capabilities of their child. More specifically, the finding that the youngest preterm infants engage in both stabilizing activities to maintain interaction and "avoidance" signals to discourage interaction suggests the possibility of teaching parents to monitor these cues and use them to modulate their interaction with their infants. Finally, the information that sick infants respond to the combination of talking and touching with increased "avoidance" signals can be used to suggest to parents of sick infants that they only provide one mode of stimulation at a time.

To organize this information in a useful way for parents, a

developmental program could be instituted that would serve to inform, encourage, and support parents in their efforts to establish a relationship with their infant. In addition to encouraging talking and stroking, teaching them the behavioral capabilities of their infant, and sensitizing them to their infant's cues, such a program could also track each infant's neurological and behavioral responsiveness by means of neurological and Brazelton exams and share this progress with parents. Further, parents could be encouraged to make their own observations about their infant and record these in a regular way. Such a record, combined with periodic photographs, could serve not only as a "baby" book but also as a stimulant to parental interest in the increasing biological and social development of their infant.

How can we understand the consistent responsiveness to talking and touching described in the present study? Despite some hints of developmental change, the patterns of responsiveness in the youngest and sickest infants were similar in form to those of the older preterm infant and, in some respects, to that of the healthy fullterm infant. Degree of illness appeared to alter responsiveness but clearly did not abolish it or alter its basic form. It seems unlikely that either increased eye movement to talking or increased body movement to touching was the result of confounding factors in the experimental design, since these dependent measures changed differentially depending on the stimulus modality. Further, other dependent measures also changed differentially: Hand-to-mouth activity

occurred less during talking and more during talking and touching; crying, grimacing, yawning, and tongue protrusion also occurred less during talking and significantly more often during talking and touching. It appears, then, that even the youngest and sickest infants responded to these social stimuli with behaviors likely to attract the mothers' attention and care. Further, they were able to respond in ways that could signal their "overload." Perhaps, as Eisenberg (1978) has suggested, the infant is normally predisposed to respond to certain kinds of sensory stimuli such as talking, a predisposition which "constitutes the roots of both social and intellectual development" (p. 5). It is important not only to assess further the responsiveness of preterm infants to social stimuli but to assess also whether differential kinds of early exposure to social stimuli affect weight gain, head growth, and later performance on developmental exams. The small samples of the present study necessitate further studies of the same nature to substantiate what appear to be the early beginnings of responsiveness to social stimuli. Certainly, at the very least, the knowledge that the infant was responsive to these stimuli calls for careful examination of the caregiving environment in the intensive care nursery.

APPENDIX A

CONSENT FORM

The purpose of this research is to find out how preterm babies (born before they are due) respond to being talked to, being touched, and to a combination of being talked to and touched. It is hoped that the information gained will help health professionals to understand how the preterm baby can respond to being talked to, being touched, and a combination of the two so that they can help parents to provide the kind of stimulation which will best help their baby develop. Even though your baby might receive this treatment from the nursing staff as part of routine care, the baby's behavior is not usually recorded.

I, ______________________________, give my permission for my infant, ________________________, to have his/her behavior recorded (how much he/she is moving, whether eyes are open and shifting, and other activities such as smiling, grimacing, yawning, sucking) and heart rate tape recorded while he/she is receiving tactile stimulation (touching of the infant's arms, legs, chest or back, and head) and auditory (talking to the infant) and a combination of talking and touching lasting a total of 9 minutes from three to six times a week from birth to 37 weeks' gestational age or transfer or discharge from the ICN. In addition, he/she may be examined weekly to test neurological reflexes and responsiveness to auditory (sound), visual (seeing), and proprioceptive (being moved) stimuli as his/her condition permits and his/her primary physician feels is not harmful to the baby's condition.

I understand that Mrs. Oehler will attempt to answer any questions that I may have during the course of the study. I may withdraw my baby from the study at any time (without interfering with my baby's regular treatment). I also understand immediate necessary care is available if my baby is injured because of participating in a research project. However, there is no provision for free medical care or for monetary compensation for such injury. Further information can be obtained from the Hospital Risk Management Office, 684-5280.

____

Date ______________________________

APPENDIX B

CRITERIA FOR SCORING ON MORBIDITY SCALE

Neonatal Morbidity Scale

Name Birthweight Gestational age Apgars

Admission date

Date

Day number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Convulsions																							
Hydrocephalus																							
Intracranial hemorrhage																							
Nil per os																							
Diarrhea																							
Necrotizing enterocolitis																							
Meningitis																							
Sepsis																							
Apnea																							
Respiratory distress syndrome																							
Pneumothorax																							
Chronic lung disease																							
Congestive heart failure																							
Tracheostomy																							
Hyperbilirubinemia																							
Hypoglycemia																							
Acidosis																							
Bleeding tendency																							
Anemia																							
Perinatal asphyxia																							

Observations

Chronic lung disease

3 confirmed on X-ray, requiring ventilation
2 nasal catheter 0_2 and negative pressure box
1 extra 0_2 including 0_2 catheter (low flow 0_2)

Cardiac failure

3 intractable CCF despite vigorous treatment
2 CCF with symptoms requiring Lasix and responding to Indomethacin
1 CCF requiring digoxin (and diuretics) but condition stable (do not rate PDA with no failure)

Hyperbilirubinemia

2 exchange transfusion
1 jaundice requiring phototherapy (do not rate jaundice which is not treated with phototherapy)

Hypoglycemia

3 producing apnea or convulsions
2 requiring persistent high glucose intravenous infusion of over 10% dextrose solution
1 transient and easily corrected < 20 mg/day

Acidosis

3 pH < 7.0
2 pH between > 7.01 and 7.09
1 pH between 7.1 and 7.19

Bleeding tendency

3 fulminating disseminated intravascular coagulation or pulmonary hemorrhage
2 bleeding requiring transfusion
1 abnormal laboratory tests for coagulation;
i.e., PT > 15 seconds
PTT > 70 seconds
Platelets < 100,000

Anemia

3 life-threatening anemia requiring transfusion correction
1 anemia requiring top-up transfusion

NPO

1 if baby NPO more than 12 hours a day

Tracheotomy

3 surgery
2 problems with tracheotomy
1 satisfactory tracheotomy

Necrotizing enterocolitis

3 perforation or surgery or very poor condition
2 active necrosis with marked distention; X-ray changes confirming necrosis; concerns about perforation; or ostomy with problems in functioning
1 necrotizing diagnosis on initial X-ray; or blood in stools and patient put on total parenteral regimen; colostomy or ileostomy without problems

Meningitis

3 very poor condition; shock or convulsions
2 proven meningitis by positive blood culture; condition stable or ventricular reservoir in place
1 meningitis well controlled by antibiotics and sterile CSF

Sepsis

3 very poor condition, shock, disseminated intravascular coagulation; clinical signs of septicemia; e.g., exchange transfusion required
2 sepsis confirmed by positive blood culture; elevated WBC and condition fair. Score 2 for 48 hours after infection confirmed or infant's condition not substantially improved (look at 0_2 requirements and activity to see if better)
1 mild infection (cultures must be positive) or serious infection well controlled with antibiotics (no score for antibiotics given for suspected infection only)

WBC normal values

at birth	20,000 to 40,000
2 days	10,000 to 40,000
2 weeks	5,000 to 25,000
3 months	5,000 to 15,000

Pneumothorax

3 bilateral pneumothorax; or central cyanosis, before drain
2 pneumothorax - drain inserted
1 drain inserted and functioning satisfactorily

Apnea

3 requiring ventilation
2 requiring CPAP or bagging 3 times a day
1 requiring extra oxygen or aminophylline

Respiratory distress syndrome

3 requiring ventilation
2 requiring CPAP
1 extra 0_2 requirements

Convulsions

3 frequent motor convulsions > 6 per day
2 1-5 convulsions per day
1 anti-convulsive therapy but no seizures

Hydrocephalus

3 surgery - shunt inserted, head size rises > .5 cm day
2 rapid increase in head size > 2 cm per week or < .5 cm/day
1 hydrocephalus without increase in head circumference and good shunt functioning

Intracranial hemorrhage

3 massive I.C. hemorrhage and major symptoms such as convulsions, apnea confirmed on LP or CAT scan or ultrasound
2 moderate ICH with signs such as irritability and head retraction or ICH with residual signs. Signs may also be: decrease in hemoglobin, deterioration in baby's condition or blood in CSF
1 ICH confirmed on CAT scan, or ultrasound, with some deterioration in condition
(if ICH is confirmed on CAT scan, but patient exhibits no signs or symptoms, do not rate - not a problem)

Perinatal asphyxia

3 cardiac arrest or prolonged attempts at resuscitation at birth or during transfer, severe neurological signs, apnea or frequent convulsions. Apgar < 5 at 5 minutes of age

2 neurological abnormalities; e.g., extensor hypertonus, transient myocardic ischemia or moderate acute renal tubular necrosis

1 mild irritability or hypotonia, intubated at birth, but Apgar > 5 at 5 minutes

Diarrhea

3 severe dehydration from diarrhea; loss of 10% body weight requiring rehydration

2 moderate dehydration requiring IV fluids

1 diarrhea noted and treated by dietary restrictions only

APPENDIX C

NEUROLOGICAL ASSESSMENT

Descriptive Information

Name:

Gestational Age

Dates ________

Dubowitz ________

Sex ________

Maternal Information

Parity ________

Complications of pregnancy ________________________

Delivery Information:

Apgar:

Admission pH:

Hospital course other than neuro:

Initial Neurological Assessment

	Date	Findings
Spinal Tap		

EEG:

CT:

Ultrasound:

Transillumination:

Skull films:

Neurological findings:

Type

Intracranial hemorrhage:

Seizures

Type: None Subtle Focal clonic Multifocal clonic

tonic status

Abnormal Ocular:

Setting Sun Wandering eye movements conjugate deviation

Staring episodes sustained nystagmus marked strabismus

Initial assessment only

	Yes	No
Caput succedaneum		
Cephalhematoma		
Molding		
Facial ecchymosis		
Facial palsy		
Brachial palsy		

Other signs of birth trauma
Describe

Initial HC __________ HC at one week __________

AGA SGA LGA

Normacephalic Microcephalic Macrocephalic

Ongoing Assessment

		Week 1	2	3	4	5	6	7	8	9	10	11	12
Gestational age													
HC													
Anterior fontanel	nl												
	tense												
	depressed												
Sutures	nl												
	separated												
	overlapping												
Reflexes													
Sucking	0												
	1												
	2												
	3												
	4												
Moro	0												
	1												
	2												
	3												
	4												
Palmar grasp	0												
	1												
	2												
	3												
	4												
	5												
Rooting	0												
	1												
	2												
	3												
	4												
	5												

		Week 1	2	3	4	5	6	7	8	9	10	11	12
Placing	0												
	1												
	2												
	3												
	4												
Ankle clonus	Yes												
	No												
Plantar grasp	Yes												
	No												
Automatic walking	Yes												
	No												
Knee jerk	normal												
	slow												
	fast												
	none												
Biceps	normal												
	slow												
	fast												
	none												
Babinski	yes												
	no												
Incurvation	yes												
	no												
Crawling	yes												
	no												
Glabella	yes												
	no												
Tonic deviation	yes												
	no												
Nystagmus	yes												
	no												
Tonic neck	yes												
	no												

		Week	1	2	3	4	5	6	7	8	9	10	11	12
Pupillary light reaction														
	yes													
	no													
	delayed													
Pupils	normal													
	constricted													
	dilated													
	irregular													
Acoustic blink	yes													
	no													

<u>Tone and Postures</u>

			1	2	3	4	5	6	7	8	9	10	11	12
Head lift in prone position														
	0													
	1													
	2													
	3													
	4													
	5													
Ventral suspension														
	0													
	1													
	2													
	3													
	4													
	5													
	6													
Head control and posture when sitting														
	0													
	1													
	2													
	3													
	4													
	5													

	Week	1	2	3	4	5	6	7	8	9	10	11	12
Traction response													
0													
1													
2													
3													
4													
5													
Reaction to passive movement													
upper 0													
1													
2													
3													
lower 0													
1													
2													
3													
Spontaneous motor activity													
0													
1													
2													
3													
Spontaneous posture													
normal													
hyperextension													
opisthotonus													
<u>Alertness and Social Characteristics</u>													
State (Brazelton)													
Alert (time)													
State of consciousness													
obtunded													
comatose													
lethargic													
alert													

	Week 1	2	3	4	5	6	7	8	9	10	11	12
Crying												
normal												
stridor												
color changes												
high pitched												
weak												
Jitteriness												
absent												
incessant tremor												
clonic movements												
Response to face (Brazelton)												
Response to face and voice (Brazelton)												
Response to ball (Brazelton)												
Response to bell (Brazelton)												
Response to voice (Brazelton)												

Remarks:

Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10

Key

Sucking	0 = none
	1 = 1 or 2 sucks in 10 sec
	2 = several
	3 = long 6 sec
	4 = full and uninterrupted 15 sec
Moro	0 = no response
	1 = minimal abduction (less than 45°)
	2 = minimal arm motion
	3 = full abduction or extension or both
	4 = immediate and full response
	any handling elicits +
Palmar grasp	0 = none
	1 = incomplete flexion of fingers
	2 = complete flexion of fingers
	3 = full flexion less than 10 sec
	4 = full flexion greater than 10 sec
	5 = fingers strongly flexed and have to be retracted by E
Placing	0 = no
	1 = stimulus leg flexed and then extended = foot not placed
	2 = placing but difficult to elicit
	3 = full placing, but brief
	4 = full placing, 10 seconds
Rooting	0 = no
	1 = lip only toward stimulus
	2 = lip and tongue movements visible
	3 = full head turn toward stimulus
	4 = full head turn with lip grasping
	5 = easily elicited full turning and lip grasping

Tone and posture

Head lift in prone position

0 = no effort to clear face
1 = minimal effort involves visible contraction of neck muscles but face doesn't clear
2 = face is cleared several times for few seconds
3 = sustained head lift for 3-4 seconds
4 = head cleared for 10 seconds
5 = head is upright with face vertical to supporting surface

Ventral suspension

0 = no attempt to raise head
1 = several unsuccessful attempts to raise head
2 = weak head raising, successful but never attains horizontal plane
3 = head sustained in horizontal place for several seconds
4 = head extended with retracted shoulders
5 = head extended, shoulders, spine, and hips extended to horizontal
6 = head, shoulders, spine, hips, and knees extend above horizontal plane

Head control and posture when sitting

0 = head passively hangs
1 = head hangs but infant attempts to right
2 = head remains upright for a few moments
3 = head remains upright for 1-2 sec and upper spine straight
4 = head remains upright for 3-4 sec
5 = head held steady and upright; spine straight but needs support

Traction response

0 = head hangs passively - no attempt to right
1 = head hangs down, but infant attempts to assist slightly with head and shoulders
2 = head hangs down through 60° then infant can right
3 = head hangs down through 45° then rights
4 = can't initiate but brings head up through most of range
5 = actively pulls to sit using head and arms

Reaction to movement

0 = floppy
1 = resistance to passive motion, but falls back to initial position
2 = resistance through full range, with immediate rapid return to position
3 = resists passive motion, immediate return to initial position

Spontaneous motor activity

0 = none
1 = spontaneous activity during 30% of time
2 = spontaneous activity during 50% of time
3 = constant activity with only brief pauses

APPENDIX D

BRAZELTON NEONATAL EXAM ORIENTATION ITEMS

Orientation Response-Inanimate Visual (4 only)

1 Does not focus on or follow stimulus.
2 Stills with stimulus and brightens.
3 Stills, focuses on stimulus when presented, brief following.
4 Stills, focuses on stimulus, following for 30° arc, jerky movements.
5 Focuses and follows with eyes horizontally for at least a 30° arc. Smooth movement, loses stimulus but finds it again.
6 Follows for 30° arcs, with eyes and head. Eye movements are smooth.
7 Follows with eyes and head at least 60° horizontally, maybe briefly vertically, continuous movement, loses stimulus occasionally, head turns to follow.
8 Follows with eyes and head 60° horizontally and 30° vertically.
9 Focuses on stimulus and follows with smooth, continuous head movement horizontally, vertically, and in a circle. Follows for 120° arc.

Orientation Response-Inanimate Auditory (4, 5s)

1 No reaction.
2 Respiratory change or blink only.
3 General quieting as well as blink and respiratory changes.
4 Stills, brightens, no attempt to locate source.
5 Shifting of eyes to sound, as well as stills and brightens.
6 Alerting and shifting of eyes and head turn to source.
7 Alerting, head turns to stimulus, and search with eyes.
8 Alerting prolonged, head and eyes turn to stimulus repeatedly.
9 Turning and alerting to stimulus presented on both sides on every presentation of stimulus.

Orientation-Animate Visual (4 only)

1 Does not focus on or follow stimulus.
2 Stills with stimulus and brightens.
3 Stills, focuses on stimulus when presented, brief following.
4 Stills, focuses on stimulus, follows for 30° arc, jerky movements.

5 Focuses and follows with eyes horizontally for at least a 30° arc. Smooth movement, loses stimulus but finds it again.
6 Follows for two 30° arcs, with eyes and head.
7 Follows with eyes and head at least 60° horizontally, maybe briefly vertically, partly continuous movement, loses stimulus occasionally, head turns to follow.
8 Follows with eyes and head 60° horizontally and 30° vertically.
9 Repeatedly focuses on stimulus and follows with smooth, continuous head movement horizontally, vertically, and in a circle. Follows for 120° arc.

Orientation-Animate Auditory (4, 5)

1 No reaction.
2 Respiratory change or blink only.
3 General quieting as well as blink and respiratory changes.
4 Stills, brightens, no attempt to locate source.
5 Shifting of eyes to sound, as well as stills and brightens.
6 Alerting and shifting of eyes and head turn to source.
7 Alerting, head turns to stimulus, and search with eyes.
8 Alerting prolonged, head and eyes turn to stimulus repeatedly.
9 Turning and alerting to stimulus presented on both sides on every presentation of stimulus.

Orientation Animate-Visual and Auditory (4 only)

1 Does not focus on or follow stimulus.
2 Stills with stimulus and brightens.
3 Stills, focuses on stimulus when presented, brief following.
4 Stills, focuses on stimulus, follows for 30° arc, jerky movements.
5 Focuses and follows with eyes horizontally and/or vertically for at least a 30° arc. Smooth movement, loses stimulus but finds it again.
6 Follows for two 30° arcs, with eyes and head.
7 Follows with eyes and head at least 60° horizontally, maybe briefly vertically, partly continuous movement, loses stimulus occasionally, head turns to follow.
8 Follows with eyes and head 60° horizontally and 30° vertically.
9 Repeatedly focuses on stimulus and follows with smooth, continuous head movement horizontally, vertically, and in a circle. Follows for at least a 120° arc.

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